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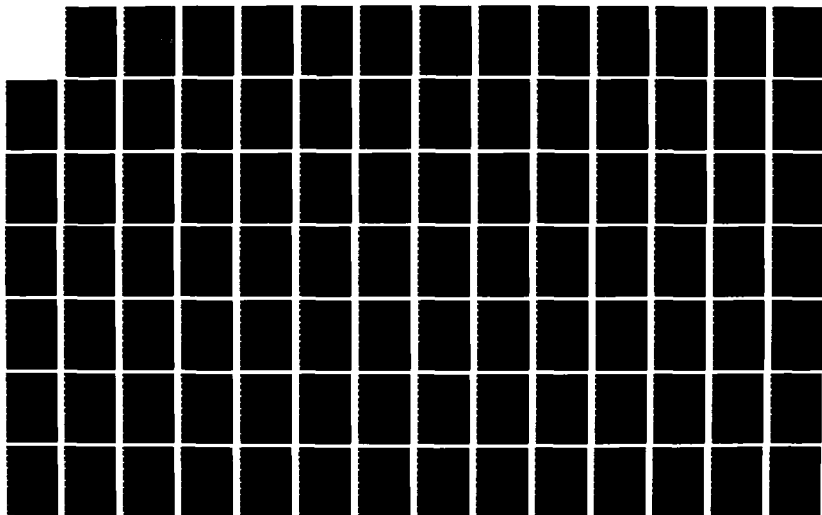
STRUCTURAL DESIGN OF COAL-FUELED POWER PLANT DUCTWORK  
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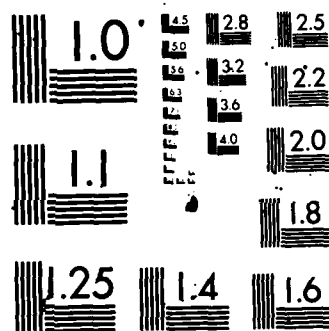
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## ABSTRACT

An absence of a comprehensive procedure for design of coal-fueled power plant ductwork currently exists in the publicly available literature. This dissertation presents such a procedure.

An overview of the ductwork design environment, including major components of the air and flue gas flow paths, design loads and temperatures, corrosion considerations, and physical configurations, is given. Design criteria for materials, corrosion inhibition, minimum plate thicknesses, temperature effects, allowable stresses and deflections, and vibrations are proposed. A detailed design procedure based on the allowable stress design philosophy is presented, and computer programs implementing the design procedure are provided. An alternate design procedure based on the Load and Resistance Factor Design approach is also discussed.

The allowable stress design procedure is applied to a horizontal section of rectangular ductwork and the results are compared to a previous design accomplished by hand calculations. The proposed design procedure provides savings in both ductwork material and fabrication labor, and consumes significantly less design time than the by-hand design approach.



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STRUCTURAL DESIGN OF COAL-FUELED POWER PLANT DUCTWORK

BY

STANLEY PEARCE RADER, 1954-

A DISSERTATION

Presented to the Faculty of the Graduate School of the

UNIVERSITY OF MISSOURI-ROLLA

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in

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1986

Wm. H. H. Ho  
Co-Advisor

Joseph W. Hume  
Co-Advisor

David R. Hume

Robert P. McBean

Wm. H. Ho

Wm. G. Andrews

## PREFACE

This dissertation represents the results of an investigation conducted during a 14 month internship with the Power Division of Black & Veatch, Engineers-Architects, in Overland Park, Kansas. The topic, structural design of coal-fueled power plant ductwork, was selected to fulfill a need in the Civil-Structural department of the Power Division. A standardized, computerized approach to ductwork design had not been documented within the department, and a rather extensive search of publicly available literature failed to produce any such publication. This study is intended to help fill that vacuum, but certainly cannot be considered to be either an exhaustive or definitive treatment of the subject. Rather, its purpose is practical: to provide a consistent, economical, efficient design method with a sound theoretical basis. While it is believed that this objective has been satisfied, it is also recognized that others may propose improvements to the assumptions or procedures presented herein. Such suggestions are welcomed and will benefit both the power industry and the clients it serves.

The reader is cautioned that independent professional judgement must be exercised when the recommendations and procedures set forth herein are applied. Anyone making use of this information assumes all liability arising from such use.

I sincerely appreciate the guidance and valuable suggestions provided by my teachers and co-advisors, Dr. Joseph H. Senne, Professor Emeritus and former Chairman of the Department of Civil Engineering, and Dr. Wei-Wen Yu, Curators' Professor of Civil Engineering, at the University of Missouri-Rolla. My deepest thanks go to my internship advisor at Black & Veatch, Dr. Robert P. McBean, supervisor of the Structural Analysis Group, and former Associate Professor of Civil Engineering at the University of Missouri-Columbia, for his perceptive insights and steady encouragement during this odyssey. I also appreciate the assistance of the other members of my advisory committee at the University of Missouri-Rolla, Dr. William A. Andrews,

Professor of Civil Engineering, Dr. H. Dean Keith, Professor of Engineering Mechanics and Assistant Dean for Graduate Affairs, School of Engineering, and Dr. Chung You Ho, Professor of Computer Science.

This study would have been impossible without the technical and administrative support provided by Black & Veatch, Engineers-Architects. I received consistently prompt and cheerful help from the Black & Veatch employees, and in particular, from Mr. Tod Sutton, who provided immeasurable aid and comfort during my battles with the computer.

The unwavering patience, understanding and support given me by my wife, Barbara, were paramount in the successful completion of this project. And I thank the Lord for giving me two sons, Nathan and John, who provided the comic relief so crucial to maintenance of a realistic perspective of it all.

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## I. INTRODUCTION

### A. BACKGROUND

The design of a modern electrical generating plant is a complex and time consuming task, involving various disciplines across the scientific and engineering spectrum. Although the structural costs of a typical coal-fueled power plant are generally less than 30% of the project total cost, the failure of any structural component can be economically devastating, costing the utility as much as \$100,000 per day for replacement power. This "low cost percentage versus high required reliability" characteristic of the structural components of a power plant tends to influence structural engineers to forgo detailed materials saving designs (such as might be achieved with finite element analysis) in favor of quicker, more general methods. Although these methods may result in the use of more or stronger materials than technically required, they have traditionally been economically justifiable, particularly in light of the owner's vested interest in holding the design and construction time to a minimum. However, the ascendancy of computer-aided design has enabled design firms to increasingly refine their designs, thus providing owners with more economical structures while simultaneously reducing their own design durations.

One facet of the structural design of a coal-fueled power plant in which such design streamlining may be achieved involves the design of the ductwork which handles gases exhausted from the steam generator (or boiler) and routed through the air quality control equipment to the chimney. The purpose of the author's internship at Black & Veatch, Engineers-Architects, was to develop a technical guide and accompanying computer programs to be used by engineers in the Power Division for design of these large steel ducts.

### B. DUCTWORK DESIGN ASPECTS

In order that the reader may appreciate the design environment, a brief description of the factors affecting ductwork design is presented.



1. Power Plant Components. Although specific configurations of modern power plants vary depending upon both owner and designer preferences, all have certain components in common. This presentation addresses ductwork in balanced-draft coal-fueled power plants. The descriptions following cover major items of equipment associated with the air and flue gas flow path in a single power generation unit at a typical plant. Most power plants have several units so that power generation can continue even though one or more units may be down for maintenance or repairs, or due to low power demand. It will be helpful for the reader to refer to the schematic diagram shown in Figure 1 as the different components are discussed.

a. Steam Generator. Commonly called the boiler, the steam generator includes a combustion chamber in which pulverized coal is burned and high pressure piping in which steam is created. The steam drives the turbine that powers the electrical generator.

b. Air Heater. The air heater is a heat exchanger in which heat is extracted from the exhaust gases of the steam generator and used to raise the temperature of the combustion air and thus increase the efficiency of the steam generator. It is a large revolving drum consisting of a fine steel mesh with large surface area that rotates alternately through the hot flue gases and the cool combustion air, transferring heat from the former to the latter. In the air heater, the exhaust gas is typically reduced from a temperature of around 800°F to between 280°F and 325°F.

c. Forced Draft (FD) Fan. The FD fan takes air from the fresh air intake and pushes it through the air heater into the combustion chamber of the steam generator. It is either a variable speed (or two speed) centrifugal fan with backward curved airfoil blades, or a variable pitch vaneaxial flow fan.

d. Electrostatic Precipitator. Due to increasingly stringent air pollution control standards, all modern coal-fueled power plants

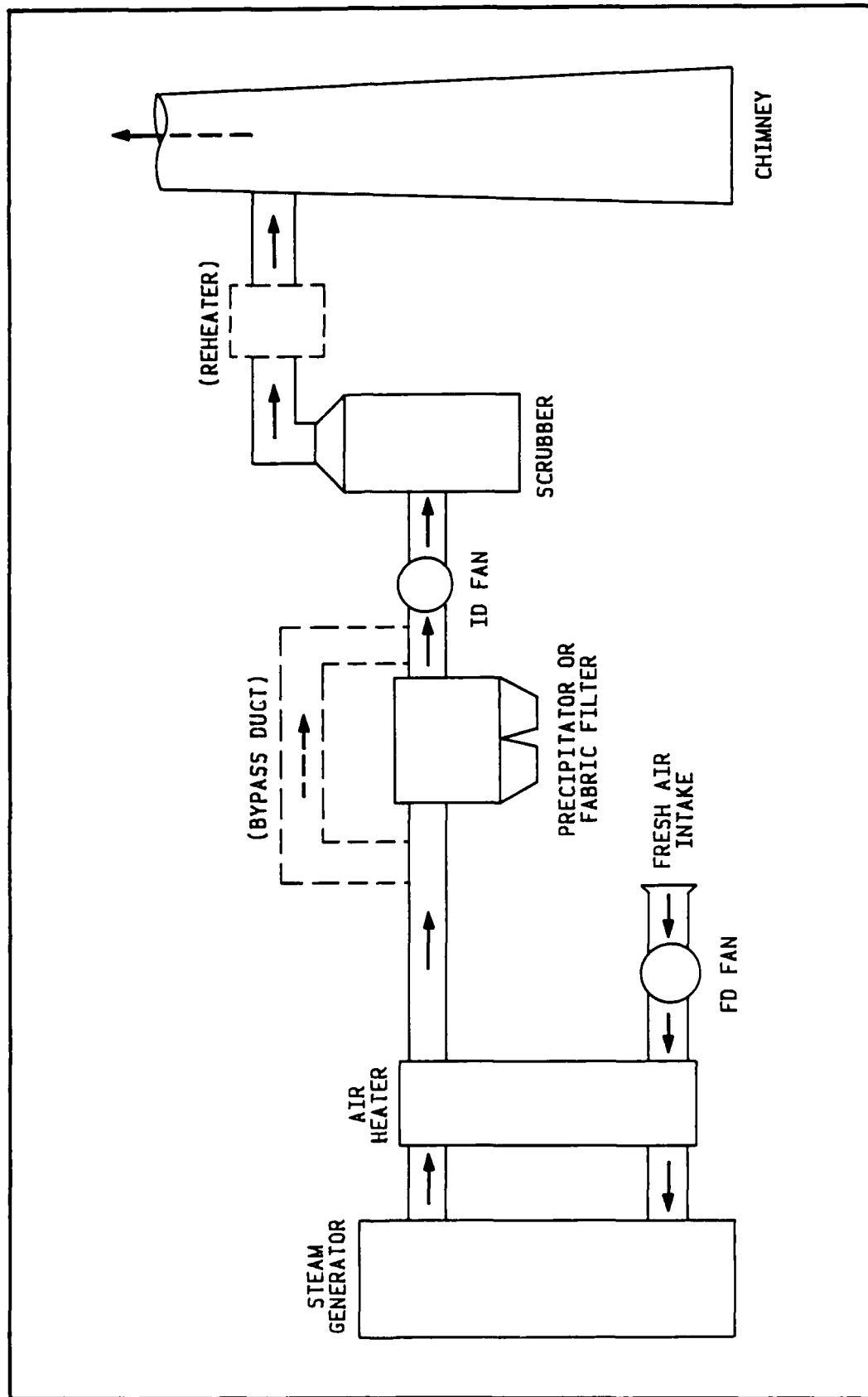


FIGURE 1. SCHEMATIC DIAGRAM OF AIR/FLUE GAS FLOW PATH IN A TYPICAL COAL-FUELED POWER PLANT

must have either a precipitator or fabric filter (see below). Designed to remove particulate matter, or fly ash, from the flue gas, the precipitator consists of a large number of electrically charged plates. As the flue gas passes through the precipitator, particles in the gas take on an electrostatic charge and are collected on the plates. Existing plants may have either a hot precipitator, located upstream of the air heater, or a cold precipitator, located after the air heater. The hot precipitator is theoretically more effective in removing particulates from the gas, but operational and maintenance problems associated with the high temperatures upstream of the air heater have rendered hot precipitators virtually obsolete with respect to new power plant designs.

e. Fabric Filter. Because a higher percentage particulate removal is possible with fabric filters, they are increasingly replacing precipitators in new designs. Commonly known as a baghouse, the fabric filter operates under the same principle as a domestic vacuum cleaner. The gas is forced through a series of fiberglass reinforced fabric bags, and particles in the gas are filtered out and deposited on the bags. Because high temperatures would destroy the bags, fabric filters are always placed downstream of the air heater, and a bypass duct is required to carry the exhaust gases around the fabric filter in case of an air heater failure.

f. Induced Draft (ID) Fan. The ID fan typically pulls gas from the boiler through the air heater and precipitator or fabric filter, and pushes it through the scrubber and up the stack. It is generally a variable speed centrifugal fan with backward curved airfoil blades, but it may be a vaneaxial fan. A unit which includes both an FD and ID fan is said to have a balanced draft system, since there is a point within the steam generator at which the gage pressure is zero. Both positive and negative internal pressures occur along the air/gas flow path between the fans.

g. Scrubber. In the majority of power plants, the scrubber is the central feature of the Flue Gas Desulfurization (FGD) system. As these names imply, the purpose of the scrubber is to remove sulfur (in the form of sulfur dioxide and trioxide) from the combustion gas. In most cases, this is accomplished by contacting the gas with an alkaline scrubbing solution, usually slurries of lime or limestone, so that the sulfur dioxide and trioxide react with calcium carbonate or hydroxide to form a solid waste product of calcium sulfite and sulfate. The majority of FGD systems have wet scrubbers, in which the gas enters at around 300°F and leaves in a saturated condition at about 125°F. Recently a few power plants have come on line with dry scrubbers, which are effective for treating flue gas from boilers burning low sulfur coals. These are sometimes placed upstream of the ID fan. Due to the limited use and applicability of dry scrubbers, this study focuses on FGD systems using wet scrubbers which are located downstream of the ID fan.

h. Chimney. The chimney, or stack, is the last component in the gas flow path. Its purpose is to disperse the flue gas into the atmosphere. Some systems include a gas reheater downstream of the scrubber to reheat the saturated gas enough to avoid condensation and the resulting formation of a sulfuric acid film on the stack lining. Whether or not a reheater is included, the primary maintenance problem associated with the chimney is corrosion of the stack liner.

2. Pressures. Normal operation vacuums and pressures in the duct system vary depending on location along the air or gas flow path. Positive internal pressure occurs from the FD fan through the air side of the air heater to the steam generator. Negative internal pressure (vacuum) occurs from the boiler downstream to the ID fan. A slight decreasing positive pressure exists from the ID fan on, until atmospheric pressure is reached at the top of the stack. Specific values for design operating pressures and vacuums vary depending upon the configuration of the system and choice of equipment. A typical

value for the design operating pressure is 14 inches  $H_2O$  (73 psf) and for the design operating vacuum is 22 inches  $H_2O$  (114 psf). Excursion pressures or vacuums may occur due to either a master fuel trip in the steam generator, or a malfunction of the FD or ID fan controls. Typical design values for excursion conditions are 26 inches  $H_2O$  (135 psf) for excursion pressure and 43 inches  $H_2O$  (224 psf) for excursion vacuum.

3. Temperatures. Gas temperatures influence the design in several ways. With high enough temperatures (above approximately 600°F) the strength and stiffness properties of the duct and stiffeners may be affected. Even at lower temperatures, thermal expansion must be considered and designed for. Also, as mentioned previously, the gas temperature can strongly influence the degree of corrosion encountered in a duct. Typical values of both normal operating and excursion temperatures for selected sections of duct are given in Table I.

a. Normal Operating Temperature. The gas temperature for use in design will generally be the normal operating temperature. This is the temperature of the gas when all components of the gas flow system are functioning as designed.

b. Excursion Temperature. Failure of the air heater or malfunction of the wet scrubber or one of the fans are occurrences that might lead to excursion temperatures as shown in Table I. Due to extensive control systems and the ability to quickly trip malfunctioning units, these temperatures generally last for only five to ten minutes.

4. Ash Buildup. Among live loads to be considered in design is the accumulation of fly ash on the bottom plate of the duct. At low power the gas velocity may not be sufficient to carry the particulate material to the fabric filter or precipitator, in which case some

TABLE I

## TYPICAL VALUES OF AIR/GAS TEMPERATURES AT SELECTED DUCT LOCATIONS

Location in Ductwork		Typical Temperature Range (°F)	
From	To	Normal Operating	Excursion
Fresh air intake	FD fan	Site mean ambient	Site extreme high or low
Steam generator	Air heater	700 to 850	700 to 850
Air heater	Precipitator or fabric filter	280 to 325	700 to 850*
Precipitator or fabric filter	Wet scrubber	280 to 325	700 to 850*
Wet scrubber	Reheater	120 to 130	550 to 650*
Reheater	Chimney	160 to 170	550 to 650*

\*These excursion temperatures are based on failure of the air heater and should not last for more than five to ten minutes for new steam generator units.

material will fall out in the ductwork. Although this ash is generally removed during periodic scheduled unit outages, it may accumulate to several feet deep in certain spots. Design live loads of nearly 200 psf for ash alone have been common in past ductwork designs.

An additional concern is the thermal stress caused by temperature differentials which may be introduced because of ash buildup. The ash acts as a thermal insulator and has a large thermal capacity. After unit shutdown, portions of the duct not in contact with the ash cool relatively quickly, while portions of the duct in contact with the hot ash remain at the hot ash temperature. The resulting thermal stresses in the ductwork can be severe. If the ash is allowed to cool and the unit is restarted without removing the ash, a similar problem occurs. In this case, portions of the duct insulated by the ambient temperature ash remain cool while the rest of the duct is raised to the temperature of the hot air or gas. Again, this temperature differential can lead to high thermal stresses in the ductwork.

5. Corrosion. Although the FGD system removes a large percentage of the sulfur from the flue gas, enough remains to cause severe corrosion problems downstream of the wet scrubber. Temperatures of around 300°F upstream of the scrubber are hot enough to maintain the sulfur in the form of sulfur dioxide and sulfur trioxide gas, and corrosion is generally not a problem. Carbon steels have proven entirely satisfactory for items exposed to the flue gas before the scrubber. Downstream of the wet scrubber, however, the gas emerges at a relatively low temperature and laden with water. Sulfur trioxide reacts with water to form sulfuric acid, which is extremely corrosive if allowed to condense on the duct. Thus, the flue gas temperature downstream of a wet scrubber should be kept above the acid dew point, but this doesn't always happen. In addition, corrosion by chlorides is common in gas ductwork. Special duct linings as well as corrosion resistant alloys are used in regions of high corrosion, but corrosion problems still persist.

6. Site Conditions. Standard design live loads to be considered include wind, snow, and seismic loads. Additionally, the designer must consider what ambient temperature to base his thermal expansion calculations on, and the erector must make appropriate modifications if the temperature at the time of erection differs from the assumed ambient temperature.

7. Ductwork Configuration. Several factors complicate the structural design of this ductwork. Some of the more prominent are mentioned below.

a. Geometric Considerations. Ideally, the ductwork should be laid out to minimize gas flow restrictions and thus keep the fan size and operating costs as small as possible. This will also minimize ash buildup. Practically, however, the layout and shape of the duct are determined to a large extent by the placement of equipment and the requirement to avoid interference with other elements of the power plant. Consequently, gas flow paths and cross-section shapes may turn out to be more complicated than would seem necessary at first glance. Since the cross-sectional area of the duct is determined by gas flow requirements and not by structural considerations, extremely large width-to-thickness ratios are commonly encountered in the duct plate, making different buckling modes of prime concern in design. Cross sections as large as 20 feet by 30 feet using 5/16 inch plate are not unusual. The structural designer is tempted to circumvent this problem by providing extensive internal bracing and trussing, but Clay<sup>1</sup> has convincingly demonstrated that the design effort and initial construction cost that might be saved by this approach would be insignificant compared to the added operational costs due to the restricted gas flow that would accompany such a design. Thus, the designer is compelled to provide ductwork with minimum internal obstructions, which is not generally compatible with the simplest structural design.



b. Thermal Expansion Joints. Although composing but a small portion of the total ductwork design, expansion joints pose a major problem both from a design and a maintenance standpoint. Determining and providing for thermal movements, and dealing with the high temperatures and corrosive environment encountered by expansion joints are prime concerns of the designer. Currently, expansion joints in ductwork are either of the metallic type, consisting of metallic bellows, or nonmetallic type, of which there are numerous configurations involving a variety of materials. The metallic type is generally favored for longevity.

c. Stiffeners. As mentioned previously, very large width-to-thickness ratios are common in design of the duct plate. Since internal longitudinal trussing is to be avoided if at all possible, external stiffeners are the order of the day in ductwork design. Historically, both longitudinal and transverse external stiffeners have been used, but the current trend is to use transverse stiffeners only, unless unusual circumstances require longitudinal ones.

d. Insulation/Lagging. After erection, most of the ductwork is covered by thermal insulation and lagging, the metal paneling which protects the insulation. This additional weight must be considered along with the dead load of the duct itself. The insulation and lagging generally weighs from 5 to 10 pounds per square foot.

### C. IMPORTANCE

Since Black & Veatch does not presently have a standardized ductwork design guide, implementation of the design procedure described herein and use of the accompanying computer programs will significantly reduce design and review hours dedicated to these exhaust ducts. Furthermore, since no industry standard exists specifically for the design of power plant exhaust ducts, the discussion and conclusions contained herein should be of general interest to the power industry.

#### D. JUSTIFICATION

Design of exhaust gas ductwork was chosen as the subject of this internship for several reasons. The completed design guide and computer program will save design hours on future projects involving ductwork and provide for standardized designs within the Power Division at Black & Veatch. In addition to being of manageable scope for a one year internship, this project satisfies the requirement of being significant, creative and independent engineering work. It provides an original contribution to both the company and to the power engineering community as a whole.

## II. REVIEW OF LITERATURE

### A. PUBLISHED LITERATURE

Prior to development of a systematic procedure for ductwork structural design, the publicly available literature was searched for information pertaining to the subject. Following is a description of the search itself, as well as the results of the investigation.

1. Scope of Search. A manual literature search of American Society of Civil Engineers' publications from 1930 to the present, as well as American Society of Mechanical Engineers' publications from 1880 to the present, was conducted. In addition, a computer-aided literature search of 10 different databases was accomplished. A brief description taken from the Dialog Database Catalog<sup>2</sup> of each database searched follows.

a. COMPENDEX. With 1,284,500 records covering 1970 to the present, COMPENDEX is the machine-readable version of Engineering Index (published by Engineering Information, Inc., New York, New York) which provides abstracted information from the world's significant engineering and technological literature.

b. CONFERENCE PAPERS INDEX. With 1,061,000 records covering 1973 to the present, CONFERENCE PAPERS INDEX (published by Cambridge Scientific Abstracts, Bethesda, Maryland) provides access to records of more than 100,000 scientific and technical papers presented at over 1,000 major regional, national, and international meetings each year. Primary subject areas covered include the life sciences, chemistry, physical sciences, geosciences, and engineering.

c. DISSERTATION ABSTRACTS ONLINE. With 845,000 records covering 1861 to the present, DISSERTATION ABSTRACTS ONLINE (published by University Microfilms International, Ann Arbor, Michigan) is a definitive subject, title, and author guide to virtually every American

dissertation accepted at an accredited institution since 1861. It also serves to disseminate citations for thousands of Canadian dissertations and an increasing number of papers accepted in institutions abroad.

d. Ei ENGINEERING MEETINGS. With 196,000 records covering 1979 to the present, Ei ENGINEERING MEETINGS (published by Engineering Information, Inc., New York, New York) is an index to significant published proceedings of engineering and technical conferences, symposia, meetings, and colloquia. It covers all areas of engineering, including civil, bioengineering, electrical, mechanical, petroleum, automotive, and aerospace.

e. ELECTRIC POWER DATABASE. With 13,000 records covering 1972 to the present, ELECTRIC POWER DATABASE (published by Electric Power Research Institute, Palo Alto, California) includes references to research and development projects of interest to the electric power industry and corresponds to the printed work Digest of Research in the Electric Utility Industry. The records include abstracts of project summaries for past and ongoing research projects.

f. FEDERAL RESEARCH IN PROGRESS. With 72,000 records, the FEDERAL RESEARCH IN PROGRESS database (published by the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia) provides access to information about ongoing federally funded research projects in the fields of physical sciences, engineering, and life sciences. Records in this database detail research either currently in progress or initiated and completed during the previous two years.

g. ISMEC (Information Service in Mechanical Engineering). With 161,000 records covering 1973 to the present, ISMEC (published by Cambridge Scientific Abstracts, Bethesda, Maryland) indexes significant articles in all aspects of mechanical engineering, production

engineering, and engineering management from approximately 250 journals published throughout the world. In addition, books, reports, and conference proceedings are indexed.

h. LC MARK. With 1,806,500 records covering 1968 to the present, the LC MARK database (published by the U.S. Library of Congress) contains complete bibliographic records for all books cataloged by the U.S. Library of Congress, beginning with books in English and adding coverage of books in other languages from 1970 through 1979.

i. NTIS. With 1,053,000 records covering 1964 to the present, the NTIS database (published by the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia) consists of government-sponsored research, development, and engineering plus analyses prepared by federal agencies, their contractors or grantees. It contains material from both the hard and soft sciences, including substantial material on technological applications, business procedures, and regulatory matters.

j. SCISEARCH. With 5,568,000 records covering 1974 to the present, SCISEARCH (published by Institute for Scientific Information, Philadelphia, Pennsylvania) is a multidisciplinary index to the literature of science and technology. It contains all the records published in Science Citation Index and additional records from the Current Contents series of publications that are not included in the printed version of Science Citation Index. SCISEARCH covers every area of the pure and applied sciences.

2. Results. The volume of published literature covering structural design of power plant air and flue gas ductwork is minuscule. Clay<sup>3</sup> does give an example of determining maximum transverse stiffener spacing for a given duct plate thickness, based on allowable stress in the plate. He also presents a method of determining stresses in transverse stiffeners connected rigidly at the duct corners.

The Sheet Metal and Air Conditioning Contractors' National Association has published a manual for rectangular industrial duct design.<sup>4</sup> In it, a table-oriented method of designing relatively small rectangular ducts using a number of conservative simplifying assumptions is presented. Its applicability to power plant ductwork design is limited, since the maximum size cross section included in the tables is 14 by 14 feet, and the only allowable plate or stiffener stress considered is 24 ksi. Humphreys<sup>5</sup> has developed a nomograph for use in design of flat plate panels with large deflections which may be used in plate thickness and stiffener spacing selection.

No other literature addressing structural ductwork design was located.

#### B. PROPRIETARY INFORMATION.

Without question, systematic design methods exist within firms that specialize in design and fabrication of large steel ducts such as are required in coal-fueled power plants. However, such information is not publicly available due to the competitive nature of the industry, and could not be obtained by the author.

### III. DESIGN CRITERIA

#### A. MATERIALS

An important step in successful design of a ductwork section is appropriate materials selection for the duct plate, corner angles, stiffeners and internal bracing. In sections of ductwork in which corrosion is not a problem, materials selection is uncomplicated. The designer's main concerns are to meet allowable stress requirements and to specify steels with good weldability. Unlined carbon and high-strength, low-alloy steels such as ASTM A36 and A588 Grade 50, respectively, are commonly used in noncorrosive environments.

The structural designer should seek the advice of a materials and corrosion expert when specifying the steel for use in corrosive environments. The chemical composition of the flue gas and associated condensation varies widely depending on such factors as the type of coal burned and the air quality control system configuration. The temperature of the flue gas also has a dramatic influence on the degree and type of corrosion present.

Currently, several different methods of corrosion protection are used. The duct may be constructed with carbon or low-alloy steel and lined with an inorganic material or ceramic. These liners may include prefired brick shapes, hydraulic-bonded concretes and mortars, or chemically-bonded concretes and mortars. Other methods of steel protection include use of rubber linings or polymeric coatings. Corrosion resistant high-nickel alloys, such as ASTM UNS Alloys N06007, N06625 and N10276 (manufacturers' designations Hastelloy G, Inconel 625 and Hastelloy C-276, respectively) are also used as duct plate or duct lining. Whatever method of corrosion protection is ultimately selected, the ductwork designer must use the appropriate structural and material properties in his design calculations and must consider any additional loads which may be introduced.

#### B. CORROSION ALLOWANCE

In addition to the corrosion protection considerations mentioned above, the designer may decide to include a corrosion allowance when

specifying the duct plate thickness. This additional thickness is generally between 1/16 and 1/8 inch. In the design procedure presented here, the additional thickness due to the corrosion allowance is not considered in the structural calculations, except that the added weight of the corrosion allowance is included in the load analysis.

#### C. MINIMUM THICKNESS

A 3/16 inch minimum plate thickness is recommended. Lighter plates may lead to excessive vibration and can present special handling problems during fabrication, transportation and erection. The designer may choose 1/4 inch as the minimum plate thickness if less than ideal handling conditions are expected.

#### D. TEMPERATURE EFFECTS

The mechanical properties of structural steels used to construct ductwork are affected by elevated temperatures due to hot flue gases. The modulus of elasticity decreases linearly from 29,000 ksi at 70°F to about 25,000 ksi at 900°F.<sup>6</sup> The yield stress may decrease as much as 30% over that same temperature range, depending on the type of steel.<sup>7</sup> Poisson's ratio, however, does not vary over this temperature range.

The designer must modify the modulus of elasticity and yield stress values used in the ductwork design when such design includes normal operating temperatures which reduce either property by over 5%. When the design operating temperature is over 370°F (the temperature at which the modulus of elasticity is reduced by 5%), the value of the modulus of elasticity used in design calculations should be modified downward based on an interpolation of the values given above. The value of the design operating temperature above which the design yield stress must be modified depends on the specific type of steel chosen. For ASTM A36 steel, the design yield stress should be reduced for design operating temperatures above 600°F (the temperature at which the yield stress is reduced by 5%).<sup>8</sup>



Design for thermal stresses caused by temperature differentials due to ash buildup (discussed in Chapter I) is not included in the design procedure contained herein. Such thermal stresses are best avoided by designing the ductwork to minimize ash fallout and by insuring that unavoidable ash buildups are removed during regularly scheduled unit outages. If these precautions fail to adequately control thermal stresses in the ductwork, corrective measures resulting from a separate investigation are required.

#### E. ALLOWABLE STRESSES

Maximum allowable stresses for the plate, corner angles, and stiffeners are based on applicable provisions of the American Institute of Steel Construction Specification for the Design, Fabrication and Erection of Structural Steel for Buildings<sup>9</sup> (hereafter referred to as the AISC Specification). Specific applications of the AISC Specification allowable stress provisions are discussed in Chapter IV.

#### F. ALLOWABLE DEFLECTIONS

Maximum allowable plate and stiffener deflections may be governed by lining manufacturer specifications if a duct lining is used. In such cases, cracking or separating of the lining due to excessive curvature of the duct plate is to be avoided. Allowable deflection limitations may also be used as a convenient method of vibration control, as discussed below. Other than these purposes, allowable deflection criteria for the plate and stiffeners are generally based on past successful duct designs using rather arbitrary deflection limitations. In the absence of the preemptive considerations discussed above, ratios of span to allowable deflection of 100 and 240 are suggested for the duct plate and stiffeners, respectively, under normal operating conditions.

#### G. VIBRATION CONSIDERATIONS

Excessive duct vibrations can normally be attributed to one of two sources. The majority of duct vibration problems occur close to the FD or ID fans and are caused by fan-induced pressure pulsations.

Rogers and Gilkey<sup>10</sup> have provided an overview of air/gas flow phenomena associated with the fans which, in some cases, can lead to pressure pulsations as high as 250 psf. They maintain that the preferred solution to fan-related excessive vibrations is to deal with the pulsation problem at its source, rather than to attempt to mask the problem by duct stiffening. Source-oriented solutions may involve installation of vanes or baffles in the vicinity of the fan, or modification of the fan inlet control, depending on the specific cause of the fan-induced pressure pulsations.

The second most common cause of duct vibrations is pressure pulsations due to turbulent air or gas flow at duct corners. The best way to avoid turbulence-induced excessive vibrations is to lay out the ductwork so that abrupt changes in the air and gas flow directions are avoided. Where sharp turns are unavoidable, turning vanes may be designed and installed to provide continuous laminar flows to the maximum extent possible.

Even when the methods of avoiding vibrations mentioned above are conscientiously applied in the planning and design process, excessive duct vibrations may still occur. Although application of these measures will certainly reduce the probability of vibration problems, the multiplicity of variables and complexity of vibration-causing phenomena make accurate prediction of all possible vibration problems highly impractical, if not impossible. The standard approach to anti-vibration design has been to apply the measures mentioned above in the original design, and then to go back in after plant start-up and take corrective action if excessive vibrations are encountered. An additional precaution may be taken in order to reduce the possibility of excessive duct vibrations. It is recommended that the allowable plate deflection under normal operating conditions be limited to one half the plate thickness in the immediate vicinity of the fans. The stiffeners in these regions should be designed such that the ratio of span to deflection is not less than 720 under normal operating conditions.

#### H. LONGITUDINAL STIFFENERS

In the vast majority of ductwork designs, the most effective use of materials is achieved by orienting stiffeners in a direction transverse to the longitudinal duct axis. However, unusual duct geometry may require the use of longitudinal stiffeners in certain instances. In such cases, the designer may refer to recommendations by Bleich,<sup>11</sup> the Structural Stability Research Council,<sup>12</sup> and Salmon and Johnson.<sup>13</sup>

#### IV. DESIGN PROCEDURE

##### A. OVERVIEW

A detailed presentation of the ductwork structural design procedure is given in Appendix B. Computer programs which implement this procedure are provided in Appendix C. This chapter provides a description of the general approach used in developing the detailed ductwork structural design procedure.

The ductwork design procedure is based on the Allowable Stress Design (ASD) philosophy. Factors of safety are applied to the plate and stiffener yield stresses to obtain allowable stresses, and the plate and stiffeners are sized such that these allowable stresses are not exceeded under the design loadings. The modes of buckling of portions of the ductwork which experience compressive loads are evaluated. Buckling is avoided by applying factors of safety to the predicted buckling stresses and sizing the compression members such that these allowable stresses are not exceeded under design loadings. Members are also sized to limit deflections to acceptable values.

Specific details of the design procedure are generated from three main sources. A Project Design Manual (hereafter referred to as the PDM) is prepared individually for each power plant project, and provides the designer with specific design information and criteria which may be unique to that project. Such information may include the basic wind speed, ground snow load, seismic zone, ambient temperature extremes, and air/flue gas design pressures and temperatures in different sections of the ductwork. Minimum thickness requirements, deflection limitations, design ash loads, and materials specifications may also be given. The American National Standard Minimum Design Loads for Buildings and Other Structures, ANSI A58.1-1982<sup>14</sup> (hereafter referred to as ANSI A58.1), provides the framework for the load analysis portion of the design procedure. The AISC Specification is the source of most of the provisions pertaining to steel design.

The design procedure begins with the load analysis. Individual design loads, including the maintenance live load, wind load, snow load, seismic load, air/gas pressure, ash load and dead loads, are

determined. The individual loads are then combined and analyzed to determine the most severe combinations of loads on both the duct plates and the transverse stiffeners. The resulting design loads are used to determine the required stiffener spacings and plate thicknesses. The individual stiffeners are then designed as either pinned-end members or as members of a rigid frame. A check of the adequacy of the duct section as a bending member follows. The section bending capacity, compression flange vertical buckling, web shear stress and combined shear and tension stress are evaluated. Finally, the bearing stiffeners are sized. A more detailed discussion of these design steps follows.

#### B. LOAD ANALYSIS

The required load analysis is quite detailed. Determination of the adjusted maintenance live load, wind load, snow load, and seismic load is based on ANSI A58.1. In addition, operating pressures or vacuums, ash live loads, and dead loads must be considered.

1. Adjusted Maintenance Live Load. Based on Section 4.10 of ANSI A58.1, Minimum Roof Live Loads, the adjusted maintenance live load may be applied to both the top and bottom duct panels. The designer may account for loads applied directly to the duct panels due to activities or materials associated with construction, maintenance, or repair through application of this load. The nominal maintenance live load, determined from the PDM, is adjusted based on both the tributary area of the structural member and the slope of the top or bottom duct panel.

2. Wind Loading. An analytical procedure based on Section 6 of ANSI A58.1 is used to determine the wind loading on the top, side, and bottom duct panels, as well as on the transverse stiffeners. A velocity pressure is calculated from the basic wind speed at the site, the importance factor for the ductwork, the height of the duct above the ground, and the exposure characteristics of the site. A gust response factor is determined based on height above the ground and exposure

conditions, and pressure coefficients are selected based on the geometry of the duct. The velocity pressure, gust response factor, and pressure coefficient are then used to calculate the design wind pressure for the duct panels and stiffeners.

3. Snow Loading. As specified in ANSI A58.1, Section 7, the design snow load is based on the ground snow load at the site, the exposure of the duct to wind, the importance factor for the ductwork, the slope of the top duct panel, and the presence or absence of heated air or gas in the duct.

4. Seismic Loading. Due to the relatively small mass of the ductwork, it is unlikely that seismic loading combinations will govern the design. The one possible exception is seismic forces associated with longitudinal movement of the duct, which must be considered when designing ductwork supports. Nevertheless, an equivalent distributed transverse seismic load is calculated based on the provisions of ANSI A58.1, Section 9, and compared to the design wind pressure to determine which loading will be further considered in design of the duct plate and stiffeners.

5. Air/Gas Pressures and Vacuums. As discussed in Chapter I, air and gas operating pressures may differ in magnitude from operating vacuums for different portions of the ductwork. In addition, the design excursion pressure may differ from the design excursion vacuum for the same portion of ductwork. The designer obtains specific values for air or gas operating and excursion pressures and vacuums from the PDM and incorporates them into the plate or stiffener load determination procedure as discussed in Paragraphs C and D following.

6. Ash Live Load. The design ash live load on the bottom duct panel is specified in the PDM. The designer has the option of applying a percentage of the ash live load on the bottom panel to the side panels to account for the hydrostatic type loading due to ash buildup against the base of the duct side panels.

7. Dead Loads. The weight of the duct plate and any duct lining material must be considered when designing the duct plate. Insulation and lagging which may be attached to the exterior of the duct are designed and fastened in such a manner that the entire dead load of the insulation and lagging is transferred directly to the stiffeners and does not affect the plate design.

In addition to the plate dead load, duct lining dead load, and insulation and lagging dead load, the weight of the stiffener itself must be considered in the stiffener design. For design of the vertical stiffeners, weights of the duct corner angles and any internal bracing not directly adjacent to duct supports must also be considered, due to the presence of tension field action in the duct webs.

#### C. PLATE LOAD DETERMINATION

When lagging is attached to the duct exterior, the lagging transfers all insulation and lagging dead loads, snow loads, maintenance live loads on the top panel, and wind loads directly to the stiffeners, so that the duct plate itself does not resist these loads. When lagging is not present, however, the duct plate must be designed to resist these loads in addition to the plate dead load, duct lining dead load, operating and excursion pressures or vacuums, maintenance live load on the bottom panel, and ash live load, as applicable.

Three different loading conditions corresponding to three different allowable stresses must be evaluated for each of the four sides of the duct. First, the maximum loading associated with normal operating conditions and no wind or seismic forces is determined. This loading is used in conjunction with unmodified allowable stresses in determining an initial plate thickness and stiffener spacing for each duct side. Second, the maximum loading combination including wind or seismic forces is calculated. The allowable stresses are increased by one third when this loading combination is applied, as allowed by Section 1.5.6 of the AISC Specification. Finally, the maximum loading including excursion pressures or vacuums is determined. When this loading combination is applied, the maximum stress

in the plate is allowed to reach the plate yield stress. The second and third loading combinations and associated allowable stresses are used to check the initial plate thicknesses and stiffener spacings selected using normal operating conditions, no wind or seismic forces, and unmodified allowable stresses.

Because (a) three different loading conditions must be considered, (b) insulation and lagging may or may not be present, and (c) the specific loads to be applied to the top, sides and bottom of the duct differ, a total of 30 different possible controlling transverse load combinations exist for the four duct sides. The desirability of computer analysis for the plate load combinations is obvious.

#### D. STIFFENER LOAD DETERMINATION

The same matrix of considerations discussed under plate load determination, with the exception of the lagging variable, exists for stiffener load determination. Stiffener load determination, however, is further complicated by introduction of another variable involving the stiffener end conditions. The designer may choose to design the stiffeners as pinned-end beams and beam-columns, with lengths equal to the widths and heights of the duct sides stiffened. In this case, the stiffener connections at the duct corners are designed to be nonmoment-resisting, or pinned, and internal bracing is generally required to maintain the shape of the ductwork during erection and under load. The alternate approach is to design the stiffeners as a rigid frame encircling the duct. This latter option requires that the stiffener corner connections be moment-resisting, or rigid.

1. Pinned-End. Stiffener load determination when stiffeners are designed as pinned-end beams and beam-columns is very similar to the plate load determination procedure described above. The weight of the stiffener is an additional consideration, but the number of possible load combinations is reduced because all plate loads and lagging loads, if present, are transferred to the stiffeners. Thus, the presence or absence of lagging becomes inconsequential with respect to the number of load combinations which must be examined. A total of 20



possible controlling transverse load combinations for the four sides must be evaluated for stiffeners designed as simple beams.

2. Rigid Frame. The number of possible controlling load combinations increases significantly when the transverse stiffeners are designed as rigid frames. This occurs because the presence of moment-resisting corner connections in the rigid frame allows for transfer of moments from stiffener to stiffener. Consequently, loads on one side of a duct affect the stresses in all four stiffeners, and the number of possible load combinations affecting any one stiffener increases. As in the plate load determination, three different loading cases corresponding to three different allowable stresses must be evaluated, and each of the three cases contains a number of different possible controlling load combinations. The total number of transverse load combinations that must be evaluated for stiffeners designed as rigid frames is 50.

#### E. PLATE THICKNESS/STIFFENER SPACING DETERMINATION

The plate thickness and stiffener spacing for each side of the duct are determined assuming that each of the four sides of the duct acts independently of the other sides. Each duct side is evaluated assuming one-way plate bending between fixed supports (the stiffeners) with a span equal to the stiffener spacing.

The design procedure is based on equations presented by Timoshenko in Theory of Plates and Shells.<sup>15</sup> It is applicable to both small and large plate deflections, where deflections greater than one half the plate thickness are considered large. The effects of both bending and membrane stresses are considered using this design method. According to Timoshenko,<sup>16</sup> the equations give good results for panels with the ratio of stiffener spacing to duct width less than 2/3; a constraint which is met in the vast majority of power plant ductwork configurations.

The maximum plate stress and deflection are calculated for each duct side over a range of stiffener spacings and plate thicknesses.

The designer has the option of selecting any plate thickness and stiffener combination which satisfies the allowable stress and deflection criteria for each of the three loading cases. For the detailed procedures presented herein, if the stiffeners are to be designed as rigid frames, the stiffener spacing selected for all four sides of the duct must be identical, but the plate thickness may vary from side to side. If the stiffeners are to be designed as simple beams, stiffener spacings for all sides should be equal to or even multiples of the minimum stiffener spacing selected. The plate thickness may vary from side to side.

#### F. STIFFENER SIZING

The procedure used to size the transverse stiffeners depends upon the type of stiffener corner connections selected. If the designer elects to use nonmoment-resisting connections, such as shown in Figure 2, the pinned-end method of stiffener sizing is used. If, however, moment-resisting corner connections, such as shown in Figure 3, are specified, the designer must use the rigid frame stiffener selection method.

In either case, a portion of the duct plate adjacent to each stiffener is considered to act in conjunction with the stiffener in resisting axial forces and bending moments. The stiffener section properties used in the design are adjusted to reflect this added contribution of the adjacent effective plate. The effective plate width is specified using a conservative form of the equation suggested by von Kármán<sup>17</sup> and modified by Sechler.<sup>18</sup>

Due to the importance of standardization in the design, fabrication, and installation of insulation and lagging on the duct exterior, all stiffeners on any one section of ductwork are designed to have the same nominal depth. This requirement applies to both pinned-end and rigid frame stiffeners. If no insulation or lagging is planned for the duct section under consideration, stiffeners on different sides of the duct may have different nominal depths.

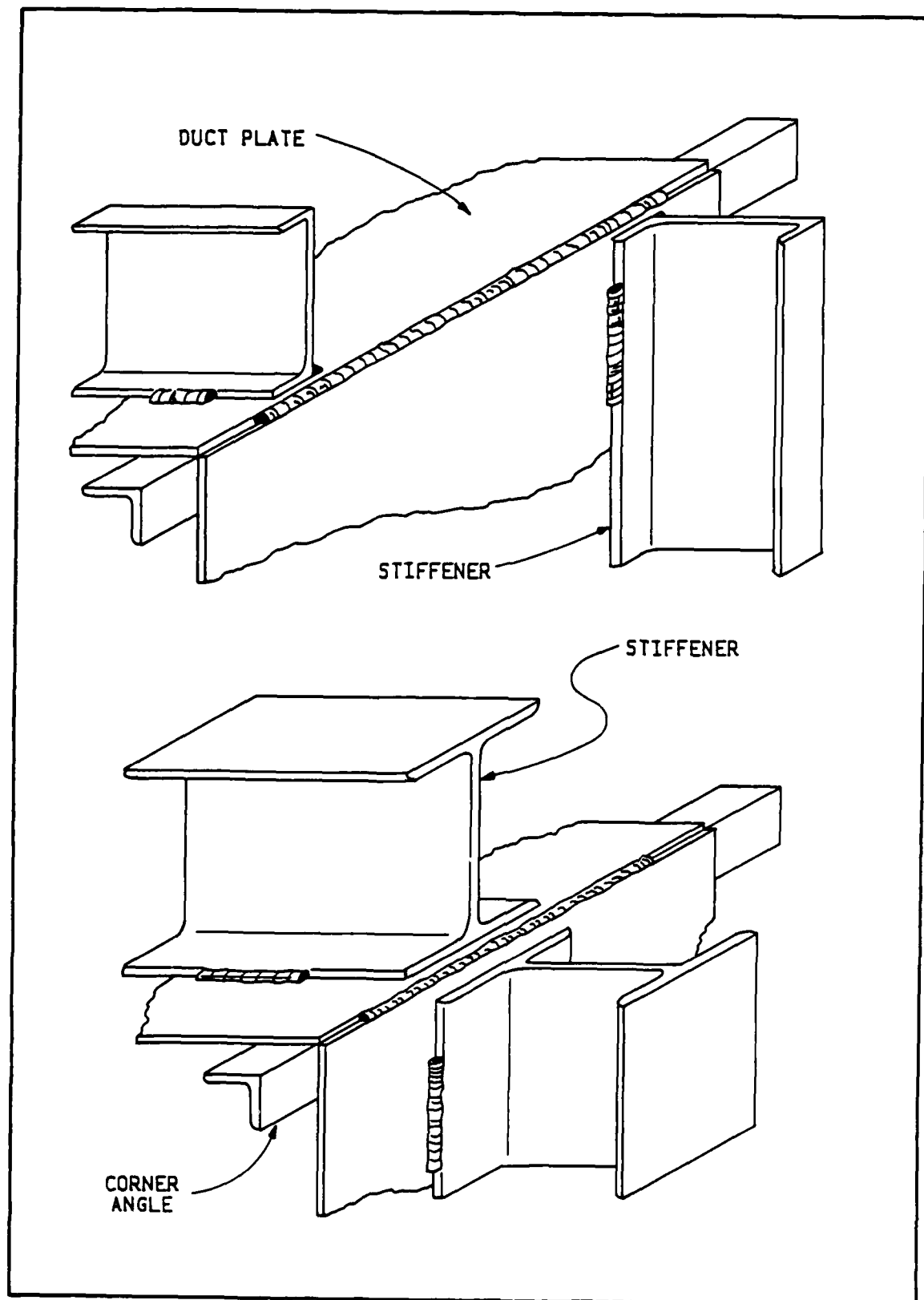


FIGURE 2. EXAMPLES OF PINNED-END STIFFENER CORNER CONNECTIONS

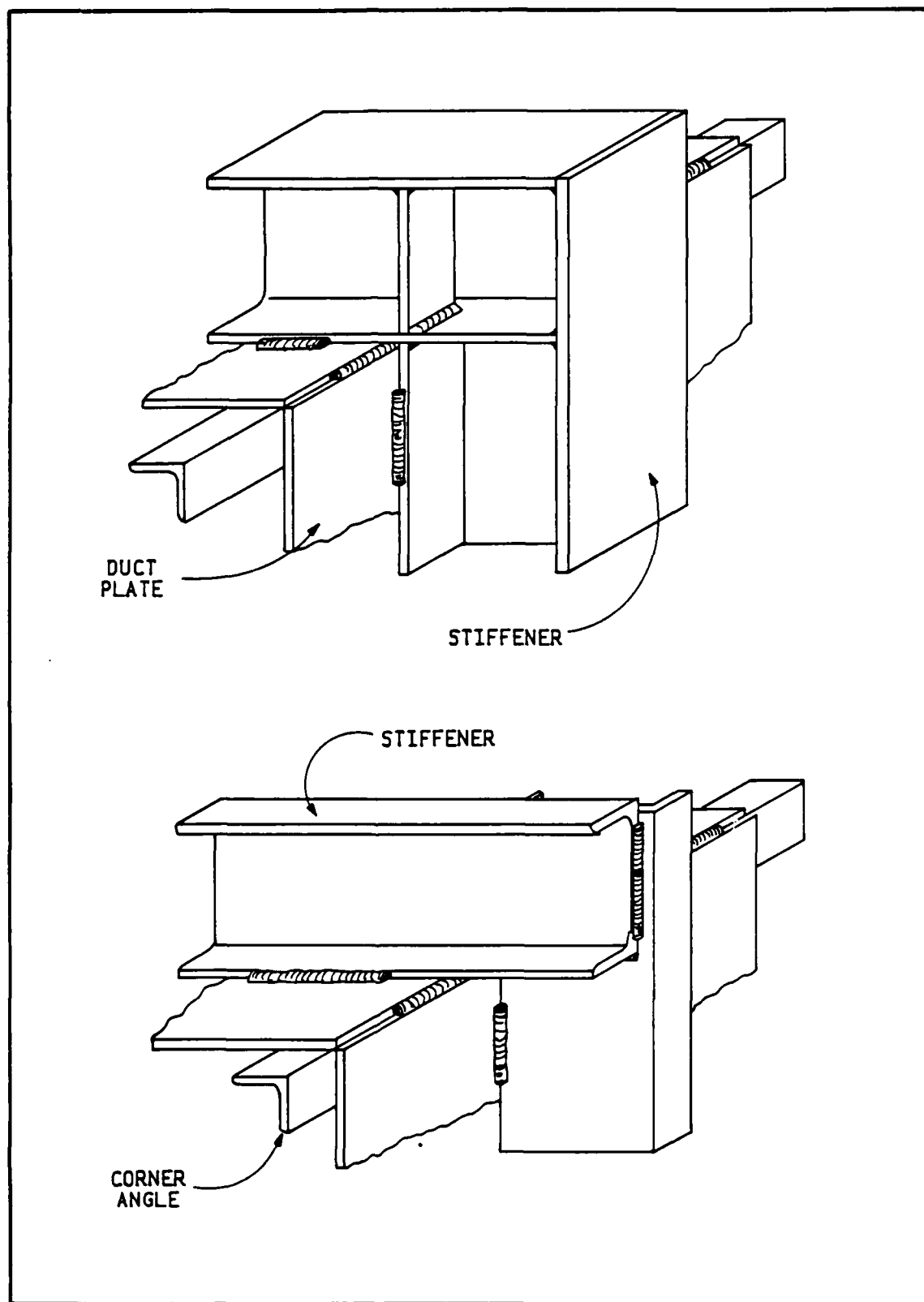


FIGURE 3. EXAMPLES OF RIGID FRAME STIFFENER CORNER CONNECTIONS

The stiffener design procedures used in both the pinned-end and rigid frame methods are based on applicable provisions in the AISC Specification.

1. Pinned-End Method. Since moments are not transferred across stiffener connections at the duct corners, each stiffener is designed independently. The top and bottom stiffeners are designed as pinned-end beam-columns under combined loading from transverse forces and axial forces due to internal pressures or vacuums. The side stiffeners are designed as pinned-end beam-columns under combined loading from transverse forces and axial forces due to tension field action and internal pressures or vacuums.

2. Rigid Frame Method. The transverse stiffeners on the four sides of the duct are joined by moment-resisting, or rigid, connections at the duct corners. They are analyzed as a rigid frame using a slope-deflection approach with matrix algebra. As with pinned-end stiffeners, the top and bottom stiffeners are subjected to transverse loads and axial loads due to internal pressures or vacuums, while the side stiffeners must be designed for these loads in addition to the axial forces due to tension field action.

#### G. DUCT SECTION CHECKS

After the plate thicknesses, stiffener spacings, and stiffener sizes have been determined, the duct section as a whole is analyzed to determine its suitability as a bending member spanning the distance between duct supports. The analysis is based on Section 1.10 of the AISC Specification, Plate Girders and Rolled Beams.

1. Bending Capacity. Due to possible buckling associated with the inherently large width-to-thickness ratios of the duct webs (side panels) and duct compression flange (top panel), the entire duct cross section cannot be considered effective in resisting the bending moment. A reduced effective compression flange width and associated

flange compressive stress are calculated using an iterative procedure based on Equation C3-1 in Appendix C, Slender Compression Elements, of the AISC Specification.

The reduced allowable compression flange stress due to the bending of the duct is then calculated from AISC Section 1.10.6, Reduction in Flange Stress, and compared to the computed stress based on the reduced effective compression flange width. If the computed effective compression flange stress is greater than the reduced allowable compression flange bending stress, the duct side and/or top plate thicknesses are increased, larger corner angles are selected, or the duct dimensions are modified to provide an increased effective section modulus.

2. Compression Flange Vertical Buckling. The majority of duct sections will not satisfy the web width-to-thickness limitations of AISC Section 1.10.2. These AISC limitations are intended to prevent vertical buckling of the compression flange into the web before attainment of yield stress in the flange due to flexure.<sup>19</sup> They are based on the assumption that the web alone provides resistance to this vertical buckling.<sup>20</sup> If the requirements of AISC Section 1.10.2 are not satisfied, the computed compressive stress in the duct compression flange based on the reduced effective compression flange width is compared to the stress above which vertical buckling of the compression flange is predicted.<sup>21</sup> If the computed compressive stress exceeds the compression flange vertical buckling stress the duct side plate thicknesses and/or top corner angle sizes are increased.

3. Web Shear. The average web shear stress is calculated and compared to the allowable web shear stress specified in AISC Section 1.10.5.2. If required, the side (vertical) stiffener spacing is decreased or the web (side plate) thickness is increased.

4. Combined Shear and Tension Stress. The combined shear and bending tensile stress in the duct web is checked in accordance with

AISC Section 1.10.7, Combined Shear and Tension Stress. If required, the web thickness is increased.

#### H. BEARING STIFFENER DESIGN

Stiffeners are designed as rigid frames around the duct perimeter at duct support points. The pinned-end stiffener design method may be used if internal cross bracing is provided, but a detailed design procedure using this approach is not included herein. Rather, the rigid frame stiffener design approach discussed previously is used with slight modification. The effective plate width adjacent to the bearing stiffeners is reduced to 12 times the plate thickness to meet the requirement of AISC Section 1.10.5.1.

The above procedure does not consider lateral loads resulting from the summation of transverse wind loads over the entire vertical projection of the duct section. Such lateral loads must be transferred to the duct supports by (a) rigid frame action of the bearing stiffeners, (b) internal cross bracing at the supports, or (c) external bumper supports. The designer must ensure that the bearing stiffeners do not become overstressed due to additional loads associated with one of these three methods of transferring the lateral wind loads to the duct supports.

## V. ALTERNATE DESIGN PROCEDURE

### A. OVERVIEW

The American Institute of Steel Construction is preparing a new steel design specification based on limit states of strength and serviceability combined with first-order probability analysis. The underlying design philosophy is called Load and Resistance Factor Design (LRFD), and is characterized by a consistent approach to strength evaluation and structural reliability.<sup>22</sup>

When published, the LRFD specification may provide the basis for an alternate method of ductwork design to the Allowable Stress Design procedure presented in Appendix B. It could prove to be more consistent and less cumbersome than the ASD approach, although the two methods should be parallel in many respects. When a design loading features a large live load to dead load ratio, application of the LRFD approach will generally result in a slightly heavier final design.<sup>23</sup> Ductwork design loads do exhibit such a ratio, but the advantages of consistency and relative simplicity associated with the LRFD approach may overshadow the slight increase in final weight.

The following comments concerning the application of the LRFD method to ductwork design are based on the unpublished Proposed Load and Resistance Factor Design Specification for Structural Steel Buildings,<sup>24</sup> dated January 1, 1985, hereafter referred to as the LRFD Specification.

### B. LOAD ANALYSIS

Determination of the adjusted maintenance live load, wind load, snow load and seismic load will be identical to the ASD approach, since both methods are based on ANSI A58.1.<sup>25</sup> The air and/or gas pressures and vacuums, ash live load, and dead loads will obviously be unchanged, since they are independent of the method of design. However, the LRFD approach differs from the ASD approach in that load factors are applied to these nominal loads before they are used in the design equations.



### C. PLATE LOAD DETERMINATION

Section A4.1, Loads, Load Factors and Load Combinations, of the proposed LRFD Specification requires that six different factored load combinations be investigated in order to determine the critical load. This additional calculation effort in the LRFD procedure is offset by the fact that evaluation of three different loading conditions corresponding to three different allowable stresses, as required in the ASD procedure, is not required. The net result is less calculation effort for the LRFD approach.

### D. STIFFENER LOAD DETERMINATION

The same factors mentioned in the discussion of plate load determination apply to the stiffener load determination. Additionally, there is the potential for a very significant reduction in calculation effort if the trial stiffeners meet the LRFD Specification requirements for design by plastic analysis. If plastic analysis is used, there is no need to differentiate between the load analysis required for pinned-end stiffeners and that required for rigid frame stiffeners. Rather than the 70 transverse load combinations associated with the pinned-end and rigid frame stiffener load determinations of the ASD approach, a total of 18 stiffener transverse load combinations must be evaluated if plastic analysis is used in the LRFD method. If plastic analysis cannot be used (stiffener geometry and section properties are such that formation of plastic hinges in the failure mechanism before buckling occurs cannot be guaranteed), the number of stiffener load combinations which must be evaluated increases significantly but remains less than that required in the ASD procedure.

### E. PLATE THICKNESS/STIFFENER SPACING DETERMINATION

The use of plastic analysis in the LRFD procedure will lead to reduced computational effort compared to the iterative method of calculating stresses and deflections based on elastic large deflection theory. It is anticipated that the LRFD approach will result in

greater stiffener spacings and/or thinner plates than the ASD procedure.

#### F. STIFFENER SIZING

As discussed above, the analysis required if the stiffeners meet the prerequisites for plastic design will be less complex than the corresponding elastic analysis required in the ASD method. The transverse stiffeners will be designed using a beam-column approach similar to that of the ASD method.

#### G. DUCT SECTION CHECKS

Since the proposed LRFD Specification section on plate girders with tension field action is comparable to that in the AISC Specification,<sup>26</sup> the duct section checks in the LRFD procedure will be quite similar to those in the ASD method.

#### H. BEARING STIFFENER DESIGN

The bearing stiffener design considerations using the ASD method, as discussed in Chapter IV, apply to bearing stiffener design under the LRFD approach also.

#### I. RECOMMENDED RESEARCH

Development of a detailed ductwork structural design procedure and associated computer programs based on the Load and Resistance Factor Design approach, as discussed in this chapter, will benefit the power industry and its clients. Application of the LRFD approach to an actual design, however, is not recommended until the American Institute of Steel Construction formally adopts and publishes the Load and Resistance Factor Design specification.

## VI. RESULTS AND DISCUSSION

### A. DESIGN EXAMPLE

In order to evaluate the effectiveness of the allowable stress design procedure presented in Chapter IV, a rectangular section of horizontal ductwork is designed using that procedure. The physical dimensions, material properties, design loads and design criteria used in this design example are specifically selected to match those of a section of ductwork designed previously by others. This previous design was fabricated, erected and put into operation in 1983.

The design parameters for both the previous and example designs are detailed in the computer output contained in Appendix D.

### B. RESULTS

Both the pinned-end and rigid frame transverse stiffener design approaches are used in the design example. Table II summarizes the previous design, while Tables III and IV present results of the pinned-end and rigid frame stiffener designs, respectively. The stiffener spacing scheme used in each of the three designs is shown in Figure 4.

### C. DISCUSSION

Comparison of Tables II, III and IV reveals that both the pinned-end and rigid frame designs result in material and fabrication labor savings compared to the previous design. No attempt is made to present the most economical design possible, in terms of material and labor costs. Rather, the two example designs are purposely similar to the previous design in order to simplify comparisons. Without this restriction, further material and labor savings could be realized in the pinned-end stiffener design by using differing stiffener spacings on the four sides of the duct, allowing deeper stiffener sections, and by using differing plate thicknesses on the four sides of the duct. The rigid frame could be similarly lightened by using deeper stiffener sections and allowing plate thicknesses to differ on the four sides of the duct.

TABLE II

## PREVIOUS DESIGN

	<u>Side 1</u>	<u>Side 2</u>	<u>Side 3</u>	<u>Side 4</u>
Plate Thickness (in.)*	.3125	.3125	.3125	.3125
Interior Panel Stiffener	30	30	30	30
Spacing (in.)				
End Panel Stiffener	30	30	30	30
Spacing (in.)				
Intermediate Transverse	WT6X11	WT6X11	WT6X11	WT6X11
Stiffeners				
Bearing Stiffeners	WT6X11	WT6X11	WT6X11	WT6X11
	<u>Corner 1</u>	<u>Corner 2</u>	<u>Corner 3</u>	<u>Corner 4</u>
Corner Angles	L3X3X1/4	L3X3X1/4	L3X3X1/4	L3X3X1/4

Duct Clear Span	47.5 ft.
Duct Height	14 ft.
Duct Width	12 ft.
Total Weight of Stiffeners	11,400 lb
Total Stiffener to Plate Weld Length (assuming 2" welds @ 6" O.C.)	693 LF

\*Including corrosion allowance.

TABLE III

## PINNED-END STIFFENER DESIGN

	<u>Side 1</u>	<u>Side 2</u>	<u>Side 3</u>	<u>Side 4</u>
Plate Thickness (in.)*	.3125	.3125	.3125	.3125
Interior Panel Stiffener Spacing (in.)	60	60	60	60
End Panel Stiffener Spacing (in.)	30	30	30	30
Intermediate Transverse Stiffeners	WT6X13	WT6X17.5	WT6X13	WT6X17.5
Bearing Stiffeners	WT6X7	WT6X15	WT6X13	WT6X15
	<u>Corner 1</u>	<u>Corner 2</u>	<u>Corner 3</u>	<u>Corner 4</u>
Corner Angles	L3X3X1/4	L3X3X1/4	L3X3X1/4	L3X3X1/4

Duct Clear Span	47.5 ft.
Duct Height	14 ft.
Duct Width	12 ft.
Total Weight of Stiffeners	10,944 lb**
Total Stiffener to Plate Weld Length (assuming 2" welds @ 6" O.C.)	485 LF***

\*Including corrosion allowance.

\*\*Represents a 4% weight savings compared to the previous design shown in Table II.

\*\*\*Represents a 30% weld length savings compared to the previous design shown in Table II.

TABLE IV

## RIGID FRAME STIFFENER DESIGN

	<u>Side 1</u>	<u>Side 2</u>	<u>Side 3</u>	<u>Side 4</u>
Plate Thickness (in.)*	.3125	.3125	.3125	.3125
Interior Panel Stiffener Spacing (in.)	60	60	60	60
End Panel Stiffener Spacing (in.)	30	30	30	30
Intermediate Transverse Stiffeners	WT6X9.5	WT6X17.5	WT6X13	WT6X17.5
Bearing Stiffeners	WT6X7	WT6X15	WT6X13	WT6X15
	<u>Corner 1</u>	<u>Corner 2</u>	<u>Corner 3</u>	<u>Corner 4</u>
Corner Angles	L3X3X1/4	L3X3X1/4	L3X3X1/4	L3X3X1/4
Duct Clear Span	47.5 ft.			
Duct Height	14 ft.			
Duct Width	12 ft.			
Total Weight of Stiffeners	10,440 lb**			
Total Stiffener to Plate Weld Length (assuming 2" welds @ 6" O.C.)	485 LF***			

\*Including corrosion allowance.

\*\*Represents an 8.4% weight savings compared to the previous design shown in Table II.

\*\*\*Represents a 30% weld length savings compared to the previous design shown in Table II.

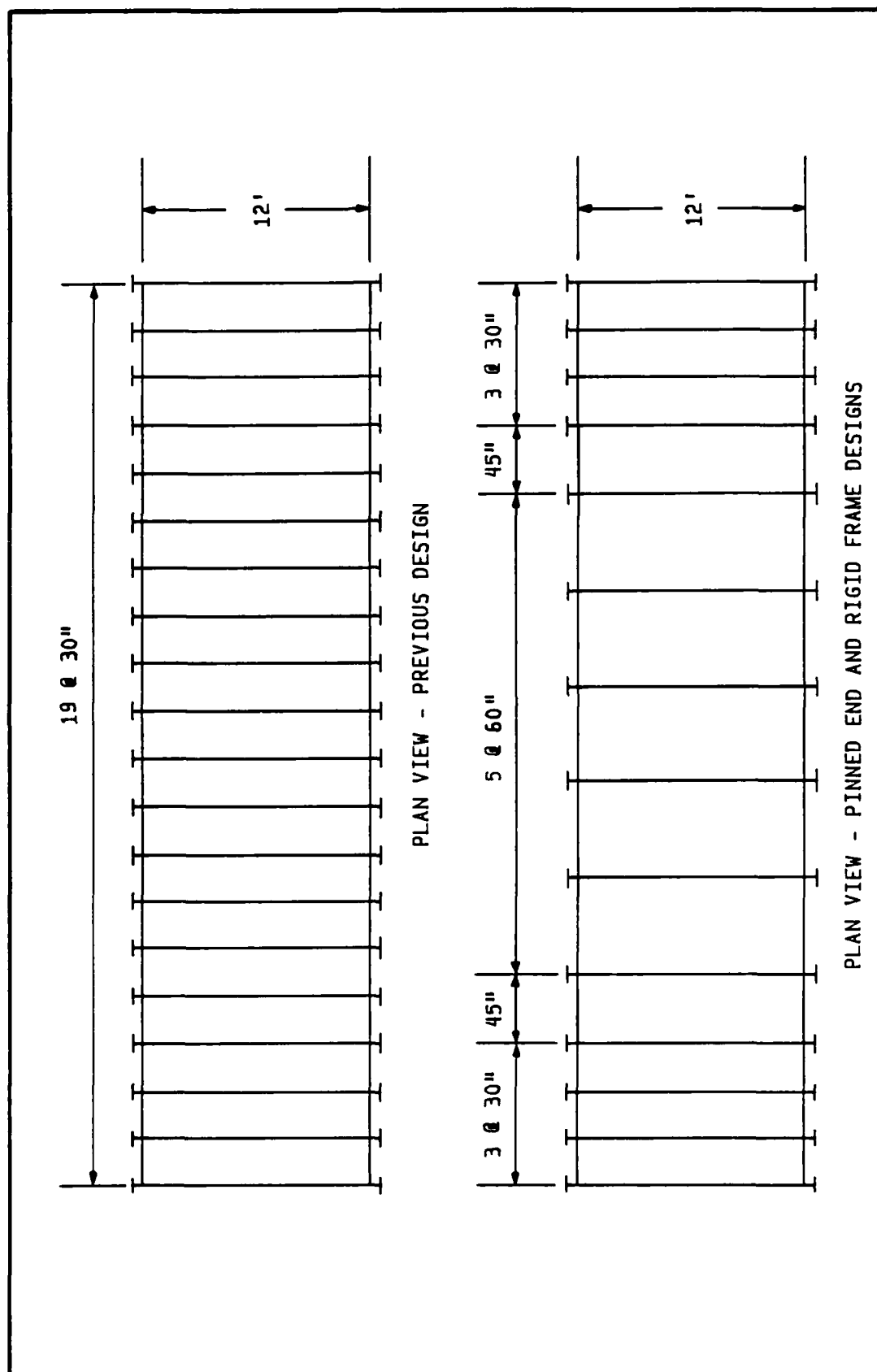


FIGURE 4. STIFFENER SPACING SCHEMES

The bearing stiffeners in both example designs are lighter than the corresponding intermediate transverse stiffeners. This apparent anomaly is explained by the fact that the bearing stiffeners are designed using end panel stiffener spacings, while the intermediate stiffeners are designed using interior panel stiffener spacings. In these examples, the latter is twice the former. Since both the transverse and axial design loads on the stiffeners increase with increasing stiffener spacing, the lighter bearing stiffeners are to be expected. In practice, however, the designer would probably specify bearing stiffeners of the same size as the heavier intermediate stiffeners, due to both practical fabrication considerations and client perceptions.



## VII. CONCLUSIONS

This study is provided to help fill a void which currently exists in the publicly available literature. The design method presented herein provides a consistent and comprehensive approach to the structural design of coal-fueled power plant ductwork. When compared to a previous design, the ductwork section designed using this procedure requires both less material and less labor during fabrication. Similar economics are expected with future designs using this method, since the computerization contained herein enables design refinements which are impractical in hand-calculated designs.

Application of this design method and the accompanying computer programs to future ductwork designs will save the design firm significant amounts of design and review time. The presence of a comprehensive, standardized design procedure will reduce the level of uncertainty associated with ductwork design and increase the speed with which engineers previously unfamiliar with this specialty may confidently produce finished ductwork designs. The engineer and his supervisor will thus gain valuable time and peace of mind, which may be profitably reinvested in solving other of the many complex problems inherent in electrical generating plant design.

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## VITA

Stanley Pearce Rader was born on March 16, 1954 in Eugene, Oregon. His primary and secondary education were completed in Burlington, Washington. He obtained his college education from the United States Air Force Academy at Colorado Springs, Colorado, and received a Bachelor of Science degree in Civil Engineering from the United States Air Force Academy in June 1976. After working as a Design Civil Engineer at Whiteman Air Force Base, Missouri, from August 1976 to June 1979, he served as a Project Engineer at Osan Air Base, Republic of Korea, from August 1979 to May 1980. He was enrolled in the Graduate School of Purdue University in West Lafayette, Indiana, from June 1980 to May 1981 and received a Master of Science degree in Civil Engineering from Purdue University in May 1981. His next assignment was to the United States Air Force Academy at Colorado Springs, Colorado, where he served as an instructor of Civil Engineering from July 1981 to May 1983.

Since June 1983 he has been enrolled in the Graduate School of the University of Missouri-Rolla, in Rolla, Missouri. He is a licensed Professional Engineer in the States of Colorado and Washington.

# APPENDIX A SYMBOLS AND NOTATION

$A_e$	= area of combined stiffener and adjacent effective plate (in. <sup>2</sup> )
$A_f$	= area of the exterior stiffener flange (in. <sup>2</sup> )
$A_{Lm}$	= cross-sectional area of corner angle m (in. <sup>2</sup> )
$A_s$	= cross-sectional area of stiffener (in. <sup>2</sup> )
$A_t$	= tributary area for calculation of maintenance live load (ft. <sup>2</sup> )
$C_b$	= bending coefficient dependent upon moment gradient
$C_c$	= column slenderness ratio separating elastic and inelastic buckling
$C_e$	= exposure factor for use in determination of snow loads for ducts
$C_{La}$	= percent ash live load coefficient (for determination of ash live load on side panels)
$C_m$	= coefficient applied to bending term in interaction formula for prismatic members and dependent upon column curvature caused by applied moments
$C_p$	= external pressure coefficient for use in determination of wind loads for ducts
$C_s$	= slope factor for use in determination of snow loads for ducts
$C_t$	= thermal factor for use in determination of snow loads for ducts
$C_v$	= ratio of "critical" web stress, according to linear buckling theory, to the shear yield stress of web material.
$D$	= flexural rigidity of a plate (kip-in.)
$D_{p,allow}$	= ratio of stiffener spacing (plate span) to allowable plate deflection
$D_{s,allow}$	= ratio of stiffener length to allowable stiffener deflection
$E_p$	= plate modulus of elasticity (ksi)
$E_s$	= stiffener modulus of elasticity (ksi)

$F_a$	= allowable axial stiffener compressive stress in the absence of bending moment (ksi)
$F'_b$	= reduced allowable bending stress in duct compression flange (ksi)
$F_{bp+}$	= allowable effective plate bending stress due to positive loads or moment in the absence of axial force (ksi)
$F_{bp-}$	= allowable effective plate bending stress due to negative loads or moment in the absence of axial force (ksi)
$F_{bs}$	= bending stress permitted in a stiffener in the absence of axial force (ksi)
$F_{bsc+}$	= allowable stiffener compressive bending stress due to positive loads or moment in the absence of axial force (ksi)
$F_{bsc-}$	= allowable stiffener compressive bending stress due to negative loads or moment in the absence of axial force (ksi)
$F_{bst+}$	= allowable stiffener tensile bending stress due to positive loads or moment in the absence of axial force (ksi)
$F_{bst-}$	= allowable stiffener tensile bending stress due to negative loads or moment in the absence of axial force (ksi)
$F'_e$	= Euler stress for a prismatic member divided by factor of safety (ksi)
$F_p$	= lateral earthquake force (lb)
$F_v$	= allowable shear stress (ksi)
$F_y$	= specified minimum yield stress of steel (ksi)
$F_{ya}$	= corner angle yield stress (ksi)
$F_{yp}$	= plate yield stress (ksi)
$F_{ys}$	= stiffener yield stress (ksi)
$G_h$	= gust response factor for main wind-force resisting system calculated at height $z = h$
$GC_p$	= product of external pressure coefficient and gust response factor for use in determination of wind loads for ducts
$H$	= vertical dimension of rectangular duct cross section; from inside surface to inside surface of top and bottom duct plates (in.)
$I$	= importance factor for use in loading analysis

$I$	= moment of inertia (in. <sup>4</sup> )
$I_{be}$	= moment of inertia of duct section based on the reduced effective compression flange width (in. <sup>4</sup> )
$I_e$	= moment of inertia of combined stiffener and adjacent effective plate (in. <sup>4</sup> )
$I_{Lm}$	= moment of inertia about horizontal axis of corner angle m (in. <sup>4</sup> )
$I_{reqd}$	= required moment of inertia (in. <sup>4</sup> )
$I_s$	= moment of inertia of stiffener (in. <sup>4</sup> )
$I_w$	= moment of inertia of vertical stiffener with reference to an axis in the plane of the adjacent duct plate (in. <sup>4</sup> )
$K$	= effective length factor for a prismatic member
$K_h$	= velocity pressure exposure coefficient evaluated at height h
$K_z$	= velocity pressure exposure coefficient evaluated at height z
$L$	= duct span; distance between duct supports (ft.)
$L_r$	= nominal maintenance live load from Project Design Manual or client criteria (psf)
$L_1$	= width of duct top panel; length of top stiffener (ft.)
$L_2$	= height of leeward duct side panel; length of leeward side stiffener (ft.)
$L_3$	= width of duct bottom panel; length of bottom stiffener (ft.)
$L_4$	= height of windward duct side panel; length of windward side stiffener (ft.)
$L_{xm}$	= length of horizontal leg of corner angle m (in.)
$L_{xt}$	= length of horizontal leg of top corner angle (in.)
$L_{yb}$	= length of vertical leg of bottom corner angle (in.)
$L_{yt}$	= length of vertical leg of top corner angle (in.)
$M_{On}$	= stiffener n fixed-end moment (kip-in.)
$M_1$	= smaller absolute value stiffener end moment (kip-in.)
$M_2$	= larger absolute value stiffener end moment (kip-in.)
$M_{ij}$	= stiffener end moment at Joint i (kip-in.)



$M_{ji}$	= stiffener end moment at Joint j, where Joint j is the joint adjacent to and clockwise from Joint i (kip-in.)
$M_{max}$	= maximum moment in a stiffener (kip-in.)
$M_{max+}$	= maximum positive moment in a stiffener (kip-in.)
$M_{max-}$	= maximum negative moment in a stiffener (kip-in.)
$M_x$	= stiffener moment at distance x clockwise from joint m (kip-in.)
$P_n$	= axial force in stiffener n (lb)
$P_{pn}$	= axial tensile force in stiffener n due to internal pressure (lb)
$P_{vn}$	= axial compressive force in stiffener n due to internal vacuum (lb)
$P_s$	= axial compressive force in vertical stiffener due to tension field action (lb)
$R_1, R_2$	= maintenance live load reduction factors
$R_3$	= ash live load reduction factor
$S_p$	= membrane force in a plate (kip/in.)
$S_{reqd,n}$	= stiffener n required section modulus (in. <sup>3</sup> )
$V$	= basic wind speed; fastest-mile wind speed at 33 feet (10 meters) above the ground of terrain exposure Category C; see ANSI A58.1-1982 Figure 1, Table 7, or Sections 6.5.2.1, 6.5.2.2, or 6.5.2.3 (mph)
$W$	= horizontal dimension of rectangular duct cross section; from inside surface to inside surface of side duct plates (in.)
$W_b$	= total weight of internal bracing in a span of ductwork (lb)
$W_p$	= weight of a portion of the duct, for use in determining seismic forces (lb)
$Z$	= numerical coefficient dependent upon seismic zone
$b$	= actual width of stiffened compression element; clear distance between compression corner angles (in.)

$b_e$	= reduced effective width of duct compression flange (in.)
$b_{en}$	= effective plate width to be used in conjunction with top, side, bottom, and side stiffeners, respectively, where $n = 1, 2, 3, 4$ (in.)
$b_f$	= stiffener flange width (in.)
$d$	= depth of stiffener section (in.)
$d'$	= depth of combined stiffener section and effective plate (in.)
$f$	= computed compressive stress in duct compression flange based on the reduced effective compression flange width (ksi)
$f_a$	= computed axial stress (ksi)
$f_{an}$	= maximum axial compressive or tensile stress in rigid frame stiffener and adjacent effective plate on side $n$ (ksi)
$f_{an+}$	= maximum axial compressive stress in pinned-end stiffener and adjacent effective plate on side $n$ (ksi)
$f_{an-}$	= maximum axial stress due to negative loading in pinned-end stiffener and adjacent effective plate on side $n$ (ksi)
$f_b$	= computed bending stress (ksi)
$f_{bp}$	= maximum bending stress in effective portion of plate adjacent to stiffener (ksi)
$f_{bp+}$	= maximum effective plate tensile bending stress under positive loading or moment (ksi)
$f_{bp-}$	= maximum effective plate compressive bending stress under negative loading or moment (ksi)
$f_{bs}$	= maximum bending stress in stiffener (ksi)
$f_{bsc+}$	= maximum stiffener tensile bending stress under positive loading or moment (ksi)
$f_{bsc-}$	= maximum stiffener compressive bending stress under negative loading or moment (ksi)
$f_{bst+}$	= maximum stiffener tensile bending stress under positive loading or moment (ksi)
$f_{bst-}$	= maximum stiffener tensile bending stress under negative loading or moment (ksi)

$f_v$	= computed shear stress (ksi)
$h$	= height of top of duct above the ground (ft.)
$k$	= factor used to calculate stiffener moments and deflections under simultaneous axial and transverse loading
$k$	= coefficient relating linear buckling strength of a plate to its dimensions and condition of edge support
$l_b$	= actual unbraced length in plane of bending (in.)
$l_n$	= maximum distance between stiffener cross sections braced against twist or lateral displacement of the exterior flange, for side $n$ (in.)
$l_{sn}$	= side $n$ stiffener length (in.)
$m$	= miles inland from hurricane oceanline; hurricane oceanlines are the Atlantic and Gulf of Mexico coastal areas
$p_g$	= ground snow load (psf)
$q$	= uniformly distributed load (psf)
$q_n$	= uniformly distributed transverse load on side $n$ duct panel (psf)
$q_{D1}$	= dead load of top duct plate (psf)
$q_{D3}$	= dead load of bottom duct plate (psf)
$q_{Dl}$	= duct lining dead load (psf)
$q_{Di}$	= insulation and lagging dead load (psf)
$q_{Ep}$	= uniformly distributed earthquake load to be applied normal to a duct panel (psf)
$q_h$	= velocity pressure calculated at height $z = h$ (psf)
$q_{La}$	= nominal ash live load (psf)
$q_{Lad}$	= adjusted ash live load (psf)
$q_{Lp}$	= operating pressure live load (psf)
$q_{Lrn}$	= adjusted maintenance live load on top or bottom duct panel, used in top and bottom plate and stiffener design (psf)
$q_{Lrd}$	= adjusted maintenance live load used in duct section design (psf)
$q_{Lv}$	= operating vacuum live load (psf)
$q_s$	= design snow load (psf)

$q_{W1}$	= design wind pressure on top panel (psf)
$q_{W2}$	= design wind pressure on leeward side panel (psf)
$q_{W3}$	= design wind pressure on bottom panel (psf)
$q_{W4}$	= design wind pressure on windward side panel (psf)
$q_{W,min}$	= minimum design wind pressure, from Project Design Manual or ANSI A58.1-1982, Section 6.4.2.1 (psf)
$q_{Xp}$	= excursion pressure (psf)
$q_{Xv}$	= excursion vacuum (psf)
$q_z$	= velocity pressure calculated at height $z$ (psf)
$r$	= radius of gyration (in.)
$r_b$	= radius of gyration about axis of concurrent bending (in.)
$r_e$	= effective radius of gyration of combined stiffener and effective plate (in.)
$r_T$	= radius of gyration of a section comprising the exterior (not attached to the duct plate) flange of the stiffener plus 1/3 of the web area on the exterior side of the stiffener neutral axis, taken about an axis in the plane of the web (in.)
$s$	= stiffener spacing (in.)
$s_n$	= side $n$ stiffener spacing (in.)
$t$	= plate thickness (in.)
$t_c$	= plate thickness of duct panel which is in compression due to gravity loads on the duct section (in.)
$t_f$	= stiffener flange thickness (in.)
$t_n$	= plate thicknesses of top, side, bottom, and side panels, respectively, where $n = 1, 2, 3, 4$ (in.)
$w$	= uniformly distributed transverse load (plf)
$w_n$	= uniformly distributed transverse load on rigid frame stiffener $n$ (plf)
$w_{n+}$	= positive uniformly distributed transverse load on pinned-end stiffener $n$ (plf)
$w_{n-}$	= negative uniformly distributed transverse load on pinned-end stiffener $n$ (plf)

- $w_{am}$  = weight per foot of top left, top right, bottom right, and bottom left corner angles, respectively, where  $m = 1, 2, 3, 4$  (plf)
- $w_{Es}$  = uniformly distributed earthquake load to be applied transversely to the side stiffeners (plf)
- $w_g$  = uniformly distributed load on duct section due to gravity loads (plf)
- $w_{sn}$  = weight per foot of top, side, bottom, and side stiffeners, respectively, where  $n = 1, 2, 3, 4$  (plf)
- $x$  = distance clockwise from Joint  $m$  (ft.)
- $y$  = distance from extreme exterior fiber to centroidal axis of stiffener (in.)
- $y'$  = distance from extreme exterior fiber to centroidal axis of combined stiffener and effective plate (in.)
- $y''$  = distance from extreme exterior compression fiber to the effective neutral axis of the duct section (in.)
- $y_{Lm}$  = vertical distance from exterior face of horizontal leg to centroid of corner angle  $m$  (in.)
- $z$  = mean height of duct above the ground; height of center line of duct above the ground (ft.)
- $\gamma_p$  = unit weight of duct plate (pcf)
- $\delta$  = deflection (in.)
- $\delta_{p,allow}$  = allowable plate deflection (in.)
- $\delta_{p,max}$  = maximum plate deflection (in.)
- $\delta_{s,allow}$  = allowable stiffener deflection (in.)
- $\delta_{s,max}$  = maximum stiffener deflection (in.)
- $\delta_{sx}$  = stiffener deflection at distance  $x$  clockwise from Joint  $m$  (in.)
- $\theta_1$  = angle between top plate and horizontal (deg.)
- $\theta_3$  = angle between bottom plate and horizontal (deg.)
- $\nu$  = Poisson's ratio
- $\sigma_1$  = constant tensile stress (membrane stress) in a one-way plate due to a distributed load acting normal to the plate (ksi)

$\sigma_2$  = maximum bending stress in a one-way plate due to a distributed load acting normal to the plate (ksi)

$\sigma_{p,max}$  = maximum duct plate stress (ksi)

$\phi_m$  = joint rotation at Joint m (rad.)

## APPENDIX B

### ALLOWABLE STRESS DESIGN PROCEDURE

#### 1. OVERVIEW

This appendix presents a detailed ductwork design procedure based on allowable stress design principles. The design procedure contained herein is the foundation upon which the computer programs contained in Appendix C are built.

The load analysis portion of the design procedure is based on American National Standard Minimum Design Loads for Buildings and Other Structures, ANSI A58.1-1982<sup>27</sup>, hereafter referred to as ANSI A58.1. The steel design portion of the design procedure is based on the American Institute of Steel Construction Specification for the Design, Fabrication and Erection of Structural Steel for Buildings<sup>28</sup>, hereafter referred to as the AISC Specification.

Numerical subscripts in this appendix refer to specific duct sides or specific duct corners as labeled in Figure 5. Symbols and notation used in this appendix are defined in Appendix A.

#### 2. LOAD ANALYSIS

Individual loads due to maintenance activities, wind, snow and earthquake are first determined. Other loads, such as operation vacuum and pressure, excursion vacuum and pressure, ash load, duct lining dead load, and insulation and lagging dead load are obtained from the Project Design Manual, hereafter referred to as the PDM. These loads are then added in different combinations to arrive at the design loads to be used in sizing the duct plate, selecting the stiffener spacing, and sizing the stiffeners.

2.1 Maintenance Live Load. Determination of the adjusted maintenance live load,  $q_{Lrn}$ , for use in design of top and bottom plates and stiffeners, is based on ANSI A58.1, Section 4.10, Minimum Roof Live Loads. The adjusted maintenance live load is applied to both the top and bottom panels of the duct.

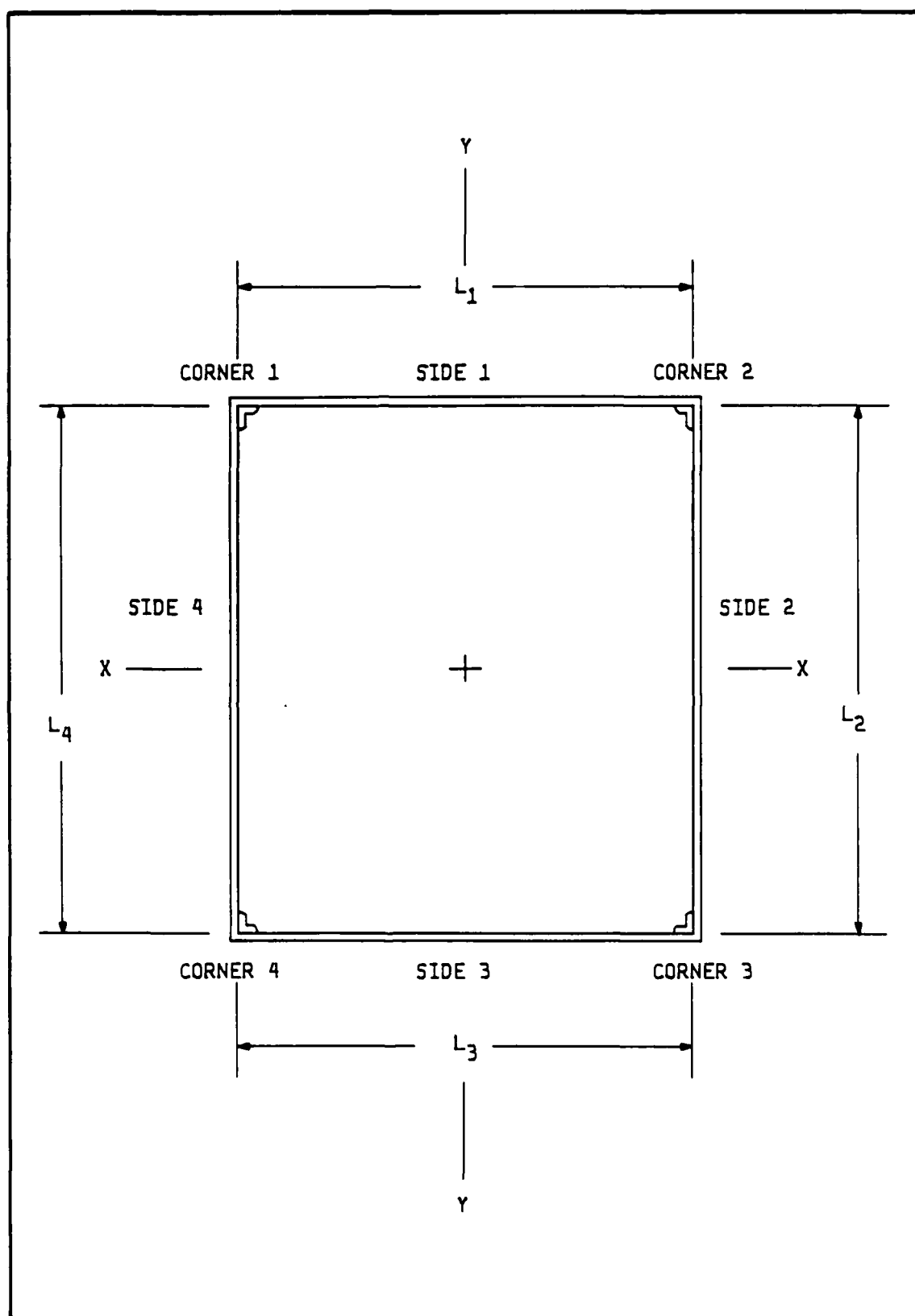


FIGURE 5. DUCT CROSS SECTION NOMENCLATURE



### 2.1.1 Required Input.

$L$  - Duct span; distance between duct supports (ft.)

$L_n$  - Width of duct top or bottom plate (ft.)

$L_r$  - Nominal maintenance live load, from PDM (psf)

$s$  - Estimated stiffener spacing (in.)

$\theta_n$  - Angle between top or bottom plate and horizontal (deg.)

### 2.1.2 Computation. From ANSI A58.1, Equation 2,

$$q_{Lrn} = L_r R_1 R_2 \geq 0.60 L_r$$

where

$q_{Lrn}$  = adjusted maintenance live load on top or bottom duct panel (psf)

$A_t$  = tributary area (ft.<sup>2</sup>)

$$= s L_n / 12$$

If  $A_t \leq 200$ , then reduction factor  $R_1 = 1$ , else,

if  $A_t \geq 600$ , then  $R_1 = 0.60$ , else

$$R_1 = 1.2 - 0.001 A_t$$

If  $\theta_n \leq 18^\circ$ , then reduction factor  $R_2 = 1$ , else,

if  $\theta_n \geq 45^\circ$ , then  $R_2 = 0.60$ , else

$$R_2 = 1.2 - 0.60 \tan \theta_n$$

2.2 Wind Loading. Wind loading on the ductwork is determined in accordance with ANSI A58.1, Section 6, Wind Loads.

### 2.2.1 Required Input.

$h$  - height of top of duct above the ground (ft.)

$L_n$  - width or height of top, leeward, bottom and windward duct panels, respectively, for  $n = 1$  to 4 (ft.)

m - miles inland from hurricane oceanline. Hurricane oceanlines are the Atlantic and Gulf of Mexico coastal areas.

$q_{w,min}$  - minimum design wind pressure, from PDM or ANSI A58.1, Section 6.4.2.1 (psf)

s - estimated stiffener spacing (in.)

V - basic wind speed; fastest-mile wind speed at 33 feet above the ground for terrain Exposure C. Determine from PDM or from ANSI A58.1 Figure 1, Table 7, or Sections 6.5.2.1, 6.5.2.2, or 6.5.2.3 (mph)

z - mean height of duct above the ground; height of center line of duct above the ground (ft.)

Exposure Category - determined according to ANSI A58.1, Section 6.5.3, or from PDM. Use of Categories C or D only is allowed.

Will the ductwork have insulation and lagging? - If so, the duct plates do not resist wind or snow loads directly, and the top panel does not resist the maintenance live load. These loads are, however, resisted by the stiffeners.

Is the ductwork directly ground supported, or elevated? - If elevated, apply a wind load to the bottom panel and stiffeners, if appropriate.

2.2.2 Computation. Although the design wind loads differ for the windward versus the leeward duct panels, both side panels are designed to resist the most severe loading involving either the windward or leeward design wind load. The specific procedure used to calculate the design wind loads depends on the height of the duct above the ground.

2.2.2.1 For  $h < 60$  ft. From ANSI A58.1, Table 4, with the internal pressure coefficient equal to zero for sealed ducts,

$$q_{wn} = q_h(GC_p) \geq q_{w,min}$$

where

$h$  = height of top of duct above the ground (ft.)

$q_{wn}$  = design wind pressure on top, leeward, bottom, or windward duct panel, respectively, for  $n = 1$  to 4 (psf)

$GC_p$  = product of external pressure coefficient and gust response factor, based on ANSI A58.1, Figures 3a and 3b, as calculated in Sections 2.2.2.1.1 through 2.2.2.1.4 following

$q_{w,min}$  = minimum design wind pressure (psf)

$q_h$  = velocity pressure calculated from ANSI A58.1, Equation 3, at height  $h$  (psf)

$$= 0.00256K_h(IV)^2$$

If  $h \leq 15$ , then  $K_h = 0.80$ , else

$$K_h = 0.369h^{2/7} \quad (\text{ANSI A58.1, Eq. A3})$$

$V$  = basic wind speed (mph)

$I$  = importance factor

$$= 1.11 - 0.0004m \geq 1.07 \quad (\text{ANSI A58.1, Table 5})$$

$m$  = miles inland from hurricane oceanline

2.2.2.1.1 Top Panel. ( $q_{w1}$ )

If  $\theta_1 \leq 10^\circ$ , then, from Figure 3b of ANSI A58.1,

if  $sL_1/12 < 10 \text{ ft.}^2$ , then  $GC_p = -1.4$ , else

$$GC_p = -1.4 + 0.2\log(sL_1/120) \leq -1.2$$

If  $10^\circ < \theta_1 \leq 30^\circ$ , then,

if  $sL_1/12 < 10 \text{ ft.}^2$ , then  $GC_p = -1.3$ , else

$$GC_p = -1.3 + 0.2\log(sL_1/120) \leq -1.1$$

If  $30^\circ < \theta_1 \leq 45^\circ$ , then,

For windward exposure:

If  $sL_1/12 < 10 \text{ ft.}^2$ , then  $GC_p = 1.3$ , else

$$GC_p = 1.3 - 0.2 \log(sL_1/120) \geq 1.1$$

For leeward exposure:

If  $sL_1/12 < 10 \text{ ft.}^2$ , then  $GC_p = -1.4$ , else

$$GC_p = -1.4 + .2 \log(sL_1/120) \leq -1.2$$

#### 2.2.2.1.2 Leeward Side Panel. ( $q_{w2}$ )

If  $\theta_1$  and  $\theta_3 \leq 10^\circ$ , then, from Figure 3a of ANSI A58.1,

if  $sL_2/4 < 10 \text{ ft.}^2$ , then  $GC_p = -1.35$ , else

$$GC_p = -1.35 + .212 \log(sL_2/120) \leq -0.99$$

If  $\theta_1$  or  $\theta_3 > 10^\circ$ , then,

if  $sL_2/12 < 10 \text{ ft.}^2$ , then  $GC_p = -1.5$ , else

$$GC_p = -1.5 + 0.235 \log(sL_2/120) \leq -1.1$$

#### 2.2.2.1.3 Bottom Panel. ( $q_{w3}$ )

$GC_p$  is calculated as in Section 2.2.2.1.1, substituting  $L_3$  for  $L_1$ , and  $\theta_3$  for  $\theta_1$ . If the duct section is directly ground supported,  $q_{w3} = 0$ .

#### 2.2.2.1.4 Windward Side Panel. ( $q_{w4}$ )

If  $\theta_1$  and  $\theta_3 \leq 10^\circ$ , then, from Figure 3a of ANSI A58.1,

if  $sL_4/12 < 10 \text{ ft.}^2$ , then  $GC_p = 1.35$ , else

$$GC_p = 1.35 - 0.265 \log(sL_4/120) \geq 0.90$$

If  $\theta_1$  or  $\theta_3 > 10^\circ$ , then,  
 if  $sL_4/12 > 10 \text{ ft.}^2$ , then  $GC_p = 1.5$ , else

$$GC_p = 1.5 - .294 \log(sL_4/120) > 1.0$$

2.2.2.2 For  $h > 60 \text{ ft.}$  Calculation of the design wind pressure is based on ANSI A58.1, Table 4.

2.2.2.2.1 Top Panel. ( $q_{w1}$ )

$$q_{w1} = q_h(GC_p) \geq q_{w,min}$$

where

$$q_h = 0.00256 K_h (IV)^2 \quad (\text{ANSI A58.1, Eq. 3})$$

For Exposure Category C:

$$K_h = .369h^{2/7} \quad (\text{ANSI A58.1, Eq. A3})$$

For Exposure Category D:

$$K_h = .696h^{1/5} \quad (\text{ANSI A58.1, Eq. A3})$$

$h$  = height of top of duct above ground (ft.)

$$I = 1.11 - .0004m \geq 1.07 \quad (\text{ANSI A58.1, Table 5})$$

$V$  = basic wind speed (mph)

If  $sL_1/12 < 10 \text{ ft.}^2$ , then  $GC_p = -2.0$ , else

$$GC_p = -2.0 + \log(sL_1/120) \leq -1.0 \quad (\text{ANSI A58.1, Fig. 4})$$

2.2.2.2.2 Leeward Side Panel. ( $q_{w2}$ )

$$q_{w2} = q_h(GC_p) \geq q_{w,min} \quad (\text{ANSI A58.1, Table 4})$$

where

$$q_h = 0.00256K_h(IV)^2 \quad (\text{ANSI A58.1, Eq. 3})$$

For Exposure Category C:

$$K_h = .369h^{2/7} \quad (\text{ANSI A58.1, Eq. A3})$$

For Exposure Category D:

$$K_h = .696h^{1/5} \quad (\text{ANSI A58.1, Eq. A3})$$

$h$  = height of top of duct aboveground (ft.)

If  $sL_2/12 < 100 \text{ ft.}^2$ , then  $GC_p = -1.1$ , else

$$GC_p = -1.1 - .429 \log(sL_2/1200) \geq -0.80 \quad (\text{ANSI A58.1, Fig. 4})$$

#### 2.2.2.2.3 Bottom Panel. ( $q_{w3}$ )

The design wind pressure on the bottom panel is calculated as in Section 2.2.2.2.1, substituting  $L_3$  for  $L_1$ .

#### 2.2.2.2.4 Windward Side Panel. ( $q_{w4}$ )

$$q_{w4} = q_z(GC_p) \geq q_{w,min} \quad (\text{ANSI A58.1, Table 4})$$

where

$$q_z = 0.00256K_z(IV)^2 \quad (\text{ANSI A58.1, Eq. 3})$$

For Exposure Category C:

$$K_z = .369z^{2/7} \quad (\text{ANSI A58.1, Eq. A3})$$

For Exposure Category D:

$$K_z = 0.696z^{1/5} \quad (\text{ANSI A58.1, Eq. A3})$$

$z$  = mean height of duct above the ground (ft.)

If  $sL_4/12 < 10 \text{ ft.}^2$ , then  $GC_p = 1.1$ , else

$$GC_p = 1.1 - .206 \log(sL_4/120) \geq 0.75$$

2.3 Snow Loading. Snow loading on the ductwork is determined in accordance with ANSI A58.1, Section 7, Snow Loads.

2.3.1 Required Input.

$p_g$  - ground snow load, determined from the PDM, or from Figures 5, 6 or 7, Table 17, or Section A7.2 of ANSI A58.1 (psf)

$\theta_1$  - angle between top of duct and horizontal

Is the power plant in Alaska?

Siting Category, from ANSI A58.1, Table 18

Is the duct section for heated air or flue gas, or for ambient temperature air?

2.3.2 Computation. The following procedure does not account for special situations in which extra-heavy drifting due to wind shadow from higher portions of the same structure or adjacent structures, or sliding of snow from the same, may occur. In such cases, the designer must increase the design snow load as appropriate.

2.3.2.1 Horizontal Top Duct Panel. ( $\theta_1 < 5^\circ$ )

For contiguous United States:

$$q_S = 1.01 C_e C_t p_g \quad (\text{ANSI A58.1, Eq. 4A})$$

For Alaska:

$$q_S = 0.86 C_e C_t p_g \quad (\text{ANSI A58.1, Eq. 4B})$$

where

$q_S$  = design snow load (psf)

$p_g$  = ground snow load (psf)

$C_e$  = exposure factor, determined from ANSI A58.1, Table 18

= 0.9 windy area with little shelter available

= 1.0 location in which snow removal by wind cannot be relied on to reduce snow load because of terrain or higher structures nearby

= 1.1 locations that do not experience much wind and where higher structures shelter the top of the duct

= 1.2 highly sheltered locations that experience little wind

$C_t$  = thermal factor, determined from ANSI A58.1, Table 19

= 1.0 flue gas or heated air ductwork

= 1.2 ambient temperature air ductwork

#### 2.3.2.2 Sloped Top Duct Panel. ( $\theta_1 > 5^\circ$ )

The sloped-surface snow load,  $q_S$ , is considered to act normal to the sloped surface. This differs from the sloped-roof snow load,  $p_s$ , calculated in ANSI A58.1, Section 7.4, which is considered to act on the horizontal projection of the sloped roof.

For contiguous United States:

$$q_S = 1.01 C_s C_e C_t p_g \quad (\text{ANSI A58.1, Eq. 4A})$$

For Alaska:

$$q_S = 0.86 C_s C_e C_t p_g \quad (\text{ANSI A58.1, Eq. 4B})$$



where

$C_s$  = slope factor, determined from ANSI A58.1, Section A7.4.

If  $C_t = 1.0$ , then

if  $\theta_1 \leq 30^\circ$ , then  $C_s = \cos \theta_1$ , else,

if  $\theta_1 > 70^\circ$ , then  $C_s = 0.0$ , else

$$C_s = [1.0 - (\theta_1 - 30^\circ)/40^\circ] \cos \theta_1$$

If  $C_t = 1.2$ , then

if  $\theta_1 \leq 45^\circ$ , then  $C_s = \cos \theta_1$ , else,

if  $\theta_1 > 70^\circ$ , then  $C_s = 0.0$ , else

$$C_s = [1.0 - (\theta_1 - 45^\circ)/25^\circ] \cos \theta_1$$

2.4 Seismic Loading. Seismic loading on the ductwork is determined in accordance with ANSI A58.1, Section 9, Earthquake Loads. Load combinations including seismic loads will rarely govern the design.

#### 2.4.1 Required Input.

$L_n$  - width or height of side n duct panel (ft.)

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{Dl}$  - duct lining dead load (psf)

$s$  - stiffener spacing (in.)

$t_n$  - side n plate thickness (in.)

$w_{sn}$  - weight per foot of stiffener n (plf)

$\gamma_p$  - unit weight of duct plate (pcf)

Seismic Zone - from PDM or ANSI A58.1, Figures 13 or 14

2.4.2 Computation. A seismic design load is calculated both for the duct plate design and the stiffener design.

### 2.4.2.1 Plate Load.

$$q_{Ep} = (12F_p)/(sL_n)$$

where

$q_{Ep}$  = uniformly distributed earthquake load to be applied normal to the duct plate, calculated as shown below (psf)

$F_p$  = lateral earthquake force applied normal to the plate, using importance factor of 1.5 and horizontal force factor of 0.3 (lb)

$$F_p = 0.45ZW_p$$

If Seismic Zone = 4,  $Z = 1$

If Seismic Zone = 3,  $Z = 3/4$

If Seismic Zone = 2,  $Z = 3/8$

If Seismic Zone = 1,  $Z = 3/16$

If Seismic Zone = 0,  $Z = 1/8$

$W_p$  = weight of plate (lb)

$$= (\gamma_p t_n/12 + q_{D1})sL_n/12$$

Combining the expressions for  $W_p$ ,  $F_p$  and  $q_{Ep}$ ,

$$q_{Ep} = .45Z(\gamma_p t_n/12 + q_{D1})$$

### 2.4.2.2 Stiffener Load.

$$w_{Es} = F_p/L_n$$

where

$w_{Es}$  = uniformly distributed earthquake load to be applied transversely to the side stiffeners (plf)

$F_p$  = lateral earthquake force applied normal to the stiffener (lb)

$$F_p = 0.45ZW_p$$

Z is as calculated in Section 2.4.2.1

$$\begin{aligned} W_p &= \text{weight of plate, stiffener, insulation, lagging, and duct lining} \\ &= (\gamma_p t_n / 12 + q_{Dl} + q_{Di}) s L_n / 12 + w_{sn} L_n \end{aligned}$$

Combining the expressions for  $W_p$ ,  $F_p$  and  $w_{Es}$ ,

$$w_{Es} = 0.45Z[(\gamma_p t_n / 12 + q_{Dl} + q_{Di}) s / 12 + w_{sn}]$$

2.5 Plate Load Determination. Three different loading cases must be considered when designing the duct plate. This is because the allowable plate stress varies depending on whether wind, seismic or excursion loads are included in the design loading combination.

The loading combinations evaluated in Sections 2.5.1, 2.5.2 and 2.5.3 are based on the assumption that when lagging is present, the lagging transfers all insulation and lagging dead loads, snow loads, maintenance live loads on the top panel, and wind loads directly to the transverse stiffeners, so that the duct plate does not directly resist these loads. When lagging is not present, however, the duct plate must be designed to withstand these loads in addition to the plate dead load, duct lining dead load, operating or excursion vacuum or pressure, maintenance live load on the bottom panel, and ash live load, as applicable.

2.5.1 Normal Operating Conditions, Excluding Wind and Seismic Effects. Maximum plate loads,  $q_1$ ,  $q_2$ ,  $q_3$  and  $q_4$ , are determined for use in conjunction with the unmodified allowable plate stress.

2.5.1.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

- $q_{D1}$  - duct lining dead load (psf)
- $q_{Dn}$  - dead load of side n duct plate (psf)  
 $= \gamma_p t_n / 12$
- $q_{La}$  - ash live load (psf)
- $q_{Lp}$  - operating pressure, from PDM (psf)
- $q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)
- $q_{Lv}$  - operating vacuum, from PDM (psf)
- $q_s$  - design snow load, from Section 2.3 (psf)
- $t_n$  - side n plate thickness (in.)
- $\gamma_p$  - unit weight of duct plate (pcf)

2.5.1.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

2.5.1.2.1 Top Panel. ( $q_1$ )

$q_1$  = maximum of 1, 2 or 3 below

1. Operating vacuum

a. With lagging

$$q_1 = q_{D1} + q_{D1} + q_{Lv}$$

b. Without lagging

$$q_1 = q_{D1} + q_{D1} + q_{Lv} + q_{Lr} + q_s$$

2. Operating pressure

With or without lagging

$$q_1 = q_{D1} + q_{D1} - q_{Lp}$$

3. Unit down (not in operation)

a. With lagging

$$q_1 = q_{D1} + q_{D1}$$

b. Without lagging

$$q_1 = q_{D1} + q_{D1} + q_{Lr} + q_s$$

2.5.1.2.2 Side Panels. ( $q_2$ ,  $q_4$ )

$q_2 = q_4$  = maximum of 1 or 2 below

## 1. Operating vacuum

With or without lagging

$$q_2 = q_4 = q_{Lv}$$

## 2. Operating pressure

With or without lagging

$$q_2 = q_4 = -q_{Lp} - C_{La} q_{La}$$

2.5.1.2.3 Bottom Panel. ( $q_3$ ) $q_3$  = maximum of 1, 2 or 3 below

## 1. Operating vacuum

With or without lagging

$$q_3 = -q_{D3} - q_{D1} + q_{Lv}$$

## 2. Operating pressure

With or without lagging

$$q_3 = -q_{D3} - q_{D1} - q_{Lp} - q_{La}$$

## 3. Unit down

With or without lagging

$$q_3 = q_{D3} - q_{D1} - q_{Lr} - q_{La}$$

2.5.2 Normal Operating Conditions, Including Wind or Seismic Effects. Maximum plate loads,  $q_1$ ,  $q_2$ ,  $q_3$  and  $q_4$ , on the top, side and bottom duct panels are determined. The allowable plate stress is increased by 1/3 when these loads are applied, per AISC Section 1.5.6. According to ANSI A58.1, Section 2.3.1, wind and seismic effects need not be assumed to act simultaneously.

2.5.2.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{D1}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{Ep}$  - uniformly distributed earthquake load, from Section 2.4 (psf)

- $q_{La}$  - ash live load (psf)
- $q_{Lp}$  - operating pressure, from PDM (psf)
- $q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)
- $q_{Lv}$  - operating vacuum, from PDM (psf)
- $q_S$  - design snow load, from Section 2.3 (psf)
- $q_{wn}$  - design wind pressure on side n duct panel, from Section 2.2 (psf)
- $t_n$  - side n plate thickness (in.)
- $\gamma_p$  - unit weight of duct plate (pcf)

2.5.2.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

2.5.2.2.1 Top Panel. ( $q_1$ )

Operating pressure, no lagging

$$q_1 = q_{D1} + q_{D1} - q_{Lp} + q_{w1}$$

(This is the only case including wind that might control design of the top panel)

2.5.2.2.2 Side Panels. ( $q_2, q_4$ )

$q_2 = q_4$  = Maximum of 1 through 7 below

1. Operating vacuum, wind
  - a. With lagging
 

Case 1, Section 2.5.1.2.2, controls
  - b. Without lagging
 
$$q_2 = q_4 = q_{Lv} + q_{w4}$$
2. Operating vacuum, earthquake
 

With or without lagging

$$q_2 = q_4 = q_{Lv} + q_{Ep}$$

3. Operating pressure, wind
  - a. With lagging  
Case 2, Section 2.5.1.2.2, controls
  - b. Without lagging  
$$q_2 = q_4 = - q_{Lp} + q_{W2} - C_{La} q_{La}$$
4. Operating pressure, earthquake  
Without or without lagging  
$$q_2 = q_4 = - q_{Lp} - q_{Ep} - C_{La} q_{La}$$
5. Unit down, windward side wind
  - a. With lagging  
$$q_2 = q_4 = 0$$
  - b. Without lagging  
$$q_2 = q_4 = q_{W4}$$
6. Unit down, leeward side wind
  - a. With lagging  
$$q_2 = q_4 = - C_{La} q_{La}$$
  - b. Without lagging  
$$q_2 = q_4 = q_{W2} - C_{La} q_{La}$$
7. Unit down, earthquake  
With or without lagging  
$$q_2 = q_4 = - q_{Ep} - C_{La} q_{La}$$

#### 2.5.2.2.3 Bottom Panel. ( $q_3$ )

$q_3$  = maximum of 2 or 3 below

1. Operating vacuum, wind  
With or without lagging  
Case 1, Section 2.5.1.2.3, controls
2. Operating pressure, wind
  - a. With lagging  
Case 2, Section 2.5.1.2.3, controls
  - b. Without lagging  
$$q_3 = - q_{D3} - q_{D1} - q_{Lp} - q_{La} + q_{W3}$$

## 3. Unit down, wind

## a. With lagging

Case 3, section 2.5.1.2.3, controls

## b. Without lagging

$$q_3 = - q_{D3} - q_{D1} - q_{Lr} - q_{La} + q_{W3}$$

2.5.3 Excursion Vacuum or Pressure Conditions.

Maximum plate loads,  $q_1$ ,  $q_2$ ,  $q_3$  and  $q_4$ , on the top, side and bottom panels are determined. The allowable plate stress may reach yield under these loads.

2.5.3.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{D1}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{La}$  - ash live load (psf)

$q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)

$q_S$  - design snow load, from Section 2.3 (psf)

$q_{Xp}$  - excursion pressure, from PDM (psf)

$q_{Xv}$  - excursion vacuum, from PDM (psf)

$t_n$  - side n plate thickness (in.)

$\gamma_p$  - unit weight of duct plate (pcf)

2.5.3.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

2.5.3.2.1 Top Panel. ( $q_1$ )

$q_1$  = Maximum of 1 or 2 below

## 1. Excursion vacuum

## a. With lagging

$$q_1 = q_{D1} + q_{D1} + q_{Xv}$$



b. Without lagging

$$q_1 = q_{D1} + q_{D1} + q_{Lr} + q_S + q_{Xv}$$

2. Excursion pressure

With or without lagging

$$q_1 = q_{D1} + q_{D1} - q_{Xp}$$

2.5.3.2.2 Side Panels. ( $q_2, q_4$ )

$q_2 = q_4$  = Maximum of 1 or 2 below

1. Excursion vacuum

With or without lagging

$$q_2 = q_4 = q_{Xv}$$

2. Excursion pressure

With or without lagging

$$q_2 = q_4 = - q_{Xp} - C_{La} q_{La}$$

2.5.3.2.3 Bottom Panel. ( $q_3$ )

$q_3$  = Maximum of 1 or 2 below

1. Excursion vacuum

With or without lagging

$$q_3 = - q_{D3} - q_{D1} + q_{Xv}$$

2. Excursion pressure

With or without lagging

$$q_{X3} = - q_{D3} - q_{D1} - q_{La} - q_{Xp}$$

2.6 Pinned-End Stiffener Load Determination. As with the plate load determination, three different loading cases must be evaluated because of differences in the allowable stiffener stresses depending on the presence or absence of wind, seismic or excursion conditions.

#### 2.6.1 Transverse Loads

2.6.1.1 Normal Operating Conditions, Excluding Wind and Seismic Effects. The maximum positive uniformly distributed transverse loads,  $w_{1+}$  through  $w_{4+}$ , and the maximum negative uniformly distributed

transverse loads,  $w_{1-}$  through  $w_{4-}$ , on the top, side and bottom stiffeners are determined. These loadings are used in conjunction with the unmodified allowable stiffener stress.

#### 2.6.1.1.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{Dl}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{La}$  - ash live load (psf)

$q_{Lp}$  - operating pressure, from PDM (psf)

$q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)

$q_{Lv}$  - operating vacuum, from PDM (psf)

$q_S$  - design snow load, from Section 2.3 (psf)

$s$  - stiffener spacing (in.)

$t_n$  - side n plate thickness (in.)

$w_{sn}$  - weight per foot of side n stiffener (plf)

$\gamma_p$  - unit weight of duct plate (pcf)

2.6.1.1.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

#### 2.6.1.1.2.1 Top Stiffener.

##### 1. Operating vacuum

$$w_{1+} = (q_{Dl} + q_{Dl} + q_{Di} + q_{Lv} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

##### 2. Operating pressure

$$w_{1-} = (q_{Dl} + q_{Dl} + q_{Di} - q_{Lp}) \frac{s}{12} + w_{s1}$$

### 2.6.1.1.2.2 Side Stiffeners.

1. Operating vacuum

$$w_{2+} = w_{4+} = \frac{q_{Lv} s}{12}$$

2. Operating pressure

$$w_{2-} = w_{4-} = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12}$$

### 2.6.1.1.2.3 Bottom Stiffener.

1. Operating vacuum

$$w_{3+} = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv}) \frac{s}{12} - w_{s3}$$

2.  $w_{3-}$  = maximum of a or b below

- a. Operating pressure

$$w_{3-} = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La}) \frac{s}{12} - w_{s3}$$

- b. Unit down

$$w_{3-} = (-q_{D3} - q_{D1} - q_{Di} - q_{Lr} - q_{La}) \frac{s}{12} - w_{s3}$$

2.6.1.2 Normal Operating Conditions, Including Wind or Seismic Effects. The maximum positive uniformly distributed transverse loads,  $w_{1+}$  through  $w_{4+}$ , and maximum negative uniformly distributed transverse loads,  $w_{1-}$  through  $w_{4-}$ , on the top, side and bottom stiffeners are determined. The allowable stiffener stress is increased by 1/3 when these loads are applied, per AISC Section 1.5.6. According to ANSI A58.1, Section 2.3.1, wind and seismic effects need not be assumed to act simultaneously.

#### 2.6.1.2.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{D1}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

- $q_{La}$  - ash live load (psf)  
 $q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)  
 $q_S$  - design snow load, from Section 2.3 (psf)  
 $q_{Wn}$  - design wind pressure on side n duct panel, from Section 2.2 (psf)  
 $s$  - stiffener spacing (in.)  
 $t_n$  - side n plate thickness (in.)  
 $w_{Es}$  - uniformly distributed earthquake load to be applied transversely to the side stiffeners, from Section 2.4.2.2 (plf)  
 $w_{sn}$  - weight per foot of side n stiffener (plf)  
 $\gamma_p$  - unit weight of duct plate (pcf)

2.6.1.2.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

2.6.1.2.2.1 Top Stiffener.

1. Operating pressure, wind

$$w_{1-} = (q_{D1} + q_{Dl} + q_{Di} - q_{Lp} + q_{W1}) \frac{s}{12} + w_{s1}$$

(This is the only case including wind or seismic forces that might control design of the top stiffener)

2.6.1.2.2.2 Side Stiffeners.

1.  $w_{2+} = w_{4+} =$  maximum of a or b below

- a. Operating vacuum, windward side wind

$$w_{2+} = w_{4+} = (q_{Lv} + q_{W4}) \frac{s}{12}$$

- b. Operating vacuum, earthquake

$$w_{2+} = w_{4+} = + \frac{q_{Lv}s}{12} + w_{Es}$$

2.  $w_{2-} = w_{4-} =$  maximum of a or b below

- a. Operating pressure, leeward side wind

$$w_{2-} = w_{4-} = (-q_{Lp} + q_{W2} - C_{La} q_{La}) \frac{s}{12}$$

b. Operating pressure, earthquake

$$w_{2-} - w_{4-} = (- q_{Lp} - C_{La} q_{La}) \frac{s}{12} - w_{Es}$$

#### 2.6.1.2.2.3 Bottom Stiffener.

1.  $w_{3-}$  maximum of a or b below

a. Operating pressure, wind

$$w_{3-} = (- q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La} + q_{W3}) \frac{s}{12} - w_{s3}$$

b. Unit down (maintenance live load), wind

$$w_{3-} = (- q_{D3} - q_{D1} - q_{Di} - q_{Lr} - q_{La} + q_{W3}) \frac{s}{12} - w_{s3}$$

2.6.1.3 Excursion Vacuum or Pressure Conditions. The maximum positive uniformly distributed transverse loads,  $w_{1+}$  through  $w_{4+}$ , and maximum negative uniformly distributed transverse loads,  $w_{1-}$  through  $w_{4-}$ , on the top, side and bottom stiffeners are determined. The allowable stiffener stress is increased by 2/3, up to a maximum equal to the yield stress, under these loads.

#### 2.6.1.3.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{D1}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{La}$  - ash live load (psf)

$q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)

$q_S$  - design snow load, from Section 2.3 (psf)

$q_{Xp}$  - excursion pressure, from PDM (psf)

$q_{Xv}$  - excursion vacuum, from PDM (psf)

$s$  - stiffener spacing (in.)

$t_n$  - side n plate thickness (in.)

$w_{sn}$  - weight per foot of side  $n$  stiffener (plf)

$\gamma_p$  - unit weight of duct plate (pcf)

2.6.1.3.2 Computation. Loads acting inward toward the duct center are considered positive. Loads acting outward away from the duct center are considered negative.

2.6.1.3.2.1 Top Stiffener.

1. Excursion vacuum

$$w_{1+} = (q_{D1} + q_{Dl} + q_{Di} + q_{Lr} + q_S + q_{Xv}) \frac{s}{12} + w_{s1}$$

2. Excursion pressure

$$w_{1-} = (q_{D1} + q_{Dl} + q_{Di} - q_{Xp}) \frac{s}{12} + w_{s1}$$

2.6.1.3.2.2 Side Stiffeners.

1. Excursion vacuum

$$w_{2+} = w_{4+} = \frac{q_{Xv}s}{12}$$

2. Excursion pressure

$$w_{2-} = w_{4-} = (-q_{Xp} - C_{La} q_{La}) \frac{s}{12}$$

2.6.1.3.2.3 Bottom Stiffener.

1. Excursion vacuum

$$w_{3+} = (-q_{D3} - q_{Dl} - q_{Di} + q_{Xv}) \frac{s}{12} - w_{s3}$$

2. Excursion pressure

$$w_{3-} = (-q_{D3} - q_{Dl} - q_{Di} - q_{La} - q_{Xp}) \frac{s}{12} - w_{s3}$$

2.6.2 Axial Loads. Internal pressures or vacuums cause axial forces in the combined stiffener and adjacent effective plate on the top, sides, and bottom of the duct. Tension field action in the duct side panels causes additional axial forces in the side (vertical) stiffeners.

2.6.2.1 Axial Force Due to Internal Pressure or Vacuum. Axial compressive forces are considered positive. Axial tensile forces are considered negative.

2.6.2.1.1 Normal Operating Conditions.

$$P_{p1} = - q_{Lp} s_1 \left( \frac{L_2 + L_4}{4} \right) \left( \frac{1 \text{ ft.}}{12 \text{ in.}} \right) = - q_{Lp} s_1 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{p2} = - q_{Lp} s_2 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{p3} = - q_{Lp} s_3 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{p4} = - q_{Lp} s_4 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{v1} = + q_{Lv} s_1 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{v2} = + q_{Lv} s_2 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{v3} = + q_{Lv} s_3 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{v4} = + q_{Lv} s_4 \left( \frac{L_1 + L_3}{48} \right)$$

where

$P_{pn}$  = axial tensile force in stiffener n due to normal operating pressure (lb)

$P_{vn}$  = axial compressive force in stiffener n due to normal operating vacuum (lb)

$q_{Lp}$  = operating pressure live load (psf)

$q_{Lv}$  = operating vacuum live load (psf)

$s_n$  = side n stiffener spacing (in.)

$L_n$  = length of side n stiffener (ft.)

2.6.2.1.2 Excursion Conditions.

$$P_{p1} = - q_{xp} s_1 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{p2} = - q_{Xp} s_2 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{p3} = - q_{Xp} s_3 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{p4} = - q_{Xp} s_4 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{v1} = + q_{Xv} s_1 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{v2} = + q_{Xv} s_2 \left( \frac{L_1 + L_3}{48} \right)$$

$$P_{v3} = + q_{Xv} s_3 \left( \frac{L_2 + L_4}{48} \right)$$

$$P_{v4} = + q_{Xv} s_4 \left( \frac{L_1 + L_3}{48} \right)$$

where

$P_{pn}$  = axial tensile force in stiffener n due to excursion pressure (lb)

$P_{vn}$  = axial compressive force in stiffener n due to excursion vacuum (lb)

$q_{Xp}$  = excursion pressure (psf)

$q_{Xv}$  = excursion vacuum (psf)

2.6.2.2 Axial Force Due to Tension Field Action. The axial compressive load on the vertical stiffeners is estimated by assuming that the tension field action results in the duct webs (side panels) behaving like Pratt trusses, with the vertical stiffeners becoming the compression struts of the truss.<sup>29</sup>

The maximum axial compressive force due to tension field action in a non-bearing stiffener occurs in the vertical stiffeners adjacent to the two supports. The value of the axial compressive force in one of these two stiffeners is

$$P_s = \frac{1}{4} \left[ w_g \left( L - \frac{s_2}{12} \right) + w_B \right]$$



where

$$w_g = \frac{\gamma_p}{12} (t_1 L_1 + t_2 L_2 + t_3 L_3 + t_4 L_4) + (q_{Di} + q_{Dl})(L_1 + L_2 + L_3 + L_4) + 12 \left[ \frac{w_{s1} L_1}{s_1} + \frac{w_{s2} L_2}{s_2} + \frac{w_{s3} L_3}{s_3} + \frac{w_{s4} L_4}{s_4} \right] + [\text{Larger of } q_{Lrd} \text{ or } q_S] L_1 + q_{Lad} L_3 + w_{a1} + w_{a2} + w_{a3} + w_{a4}$$

$$q_{Lrd} = L_r R_1 R_2 \geq 0.20 L_r$$

If  $LL_1 \leq 100 \text{ ft.}^2$ , then  $R_1 = 1$ , else

if  $LL_1 \geq 500 \text{ ft.}^2$ , then  $R_1 = 0.2$ , else

$$R_1 = 1.2 - 0.002 LL_1$$

If  $\theta_1 \leq 18^\circ$ , then  $R_2 = 1$ , else

if  $\theta_1 \geq 45^\circ$ , then  $R_2 = 0.60$ , else

$$R_2 = 1.2 - 0.6 \tan \theta_1$$

The above calculation of  $R_1$  is a modification of that given in ANSI A58.1, Section 4.10.1. Since maintenance loads on top of the duct will be applied to limited areas, the design uniformly distributed maintenance live load applied to the large tributary area of the top of the duct is significantly reduced from that applied to the much smaller stiffener tributary area previously.

$$q_{Lad} = q_{La} R_3$$

If  $LL_3 \leq 100 \text{ ft.}^2$ , then  $R_3 = 1$ , else

if  $LL_3 \geq 600 \text{ ft.}^2$ , then  $R_3 = 0.5$ , else

$$R_3 = 1.1 - 0.001 LL_3$$

The above calculation reduces the design value of the uniformly distributed ash live load for the large tributary area associated with axial loads in vertical stiffeners near the duct supports. The designer should use a more accurate value for  $q_{Lad}$  if he can determine such from modeling investigations or other sources.

In the above equations:

$P_s$  = axial compressive force in vertical stiffener due to tension field action (lb)

$w_g$  = uniform distributed load on duct due to gravity loads (plf)

$L$  = duct clear span (ft.)

$s_n$  = side n stiffener spacing (in.)

$w_B$  = weight of internal bracing in ductwork span (lb)

$\gamma_p$  = unit weight of duct plate (pcf)

$t_n$  = duct plate thickness of side n (in.)

$L_n$  = duct width or height of side n (ft.)

$q_{Di}$  = insulation and lagging dead load (psf)

$q_{Dl}$  = duct lining dead load (psf)

$w_{sn}$  = weight per foot of side n stiffener (plf)

$q_s$  = design snow load (psf)

$w_{am}$  = weight per foot of corner angle m (plf)

$q_{Lrd}$  = adjusted maintenance live load for duct section design (psf)

$L_r$  = nominal maintenance live load (psf)

$R_1, R_2$  = maintenance live load reduction factors

$q_{Lad}$  = adjusted ash live load (psf)

$q_{La}$  = nominal ash live load (psf)

$R_3$  = ash live load reduction factor

2.7 Rigid Frame Stiffener Load Determination. Three different transverse loading cases must be evaluated because of differences in the allowable stiffener stresses depending on the presence or absence of wind, seismic or excursion conditions. Each of the transverse loading cases is accompanied by simultaneous axial stiffener loading. There are four possible axial load combinations:

Axial Load Combination A: Internal Vacuum

$$P_1 = P_{v1}$$

$$P_2 = P_{v2} + P_s$$

$$P_3 = P_{v3}$$

$$P_4 = P_{v4} + P_s$$

Axial Load Combination B: Internal Pressure; Duct Section Midspan

$$\begin{aligned} P_1 &= P_{p1} \\ P_2 &= P_{p2} \\ P_3 &= P_{p3} \\ P_4 &= P_{p4} \end{aligned}$$

Axial Load Combination C: Internal Pressure; Duct Section Supports

$$\begin{aligned} P_1 &= P_{p1} \\ P_2 &= P_s \\ P_3 &= P_{p3} \\ P_4 &= P_s \end{aligned}$$

Axial Load Combination D: Unit Down

$$\begin{aligned} P_1 &= 0 \\ P_2 &= P_s \\ P_3 &= 0 \\ P_4 &= P_s \end{aligned}$$

where

$P_n$  = axial compressive force in stiffener n (lb)

$P_{vn}$  = axial compressive force in stiffener n due to internal vacuum, as calculated in Section 2.6.2.1 (lb)

$P_{pn}$  = axial tensile force in stiffener n due to internal pressure, as calculated in Section 2.6.2.1 (lb)

$P_s$  = axial compressive force in vertical stiffener due to tension field action, as calculated in Section 2.6.2.2 (lb)

**2.7.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.** Different combinations of the uniformly distributed transverse loads  $w_1$ ,  $w_2$ ,  $w_3$  and  $w_4$ , and the axial loads  $P_1$ ,  $P_2$ ,  $P_3$ , and  $P_4$  are evaluated in order to determine the required stiffener section for each side of the duct under normal operating conditions, excluding wind and seismic forces. These load combinations are used in conjunction with the unmodified allowable stiffener stress.

### 2.7.1.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{Dl}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{La}$  - ash live load (psf)

$q_{Lp}$  - operating pressure, from PDM (psf)

$q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)

$q_{Lv}$  - operating vacuum, from PDM (psf)

$q_S$  - design snow load, from Section 2.3 (psf)

$s$  - stiffener spacing (in.)

$t_n$  - side n plate thickness (in.)

$w_{sn}$  - weight per foot of side n stiffener (plf)

$\gamma_p$  - unit weight of duct plate (pcf)

2.7.1.2 Computation. Transverse loads acting inward toward the duct center and axial compressive loads are considered positive. Transverse loads acting outward away from the duct center and axial tensile loads are considered negative. The following 14 transverse load combinations are evaluated.

1. Operating vacuum, ash, maintenance live load, snow load

$$w_1 = (q_{Dl} + q_{Dl} + q_{Di} + q_{Lv} + q_{Lr} + q_S)s/12 + w_{s1}$$

$$w_2 = w_4 = (q_{Lv} - C_{La} q_{La})s/12$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} + q_{Lv} - q_{La})s/12 - w_{s3}$$

(evaluate with Axial Load Combination A)

2. Operating vacuum, ash

$$w_1 = (q_{Dl} + q_{Dl} + q_{Di} + q_{Lv}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (q_{Lv} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

3. Operating vacuum, maintenance live load, snow load

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = \frac{q_{Lv}s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

4. Operating vacuum

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = \frac{q_{Lv}s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

5. Operating pressure, ash, maintenance live load, snow load

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

6. Operating pressure, ash

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

7. Operating pressure, maintenance live load, snow load

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{q_{Lp} s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

8. Operating pressure

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{q_{Lp} s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

9. Unit down, ash, maintenance live load top and bottom, snow

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{C_{La} q_{La} s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

10. Unit down, ash, maintenance live load bottom

$$w_1 = (q_{D1} + q_{D1} + q_{Di}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{C_{La} q_{La} s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

11. Unit down, ash, maintenance live load top, snow

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{C_{La} q_{La} s}{12}$$

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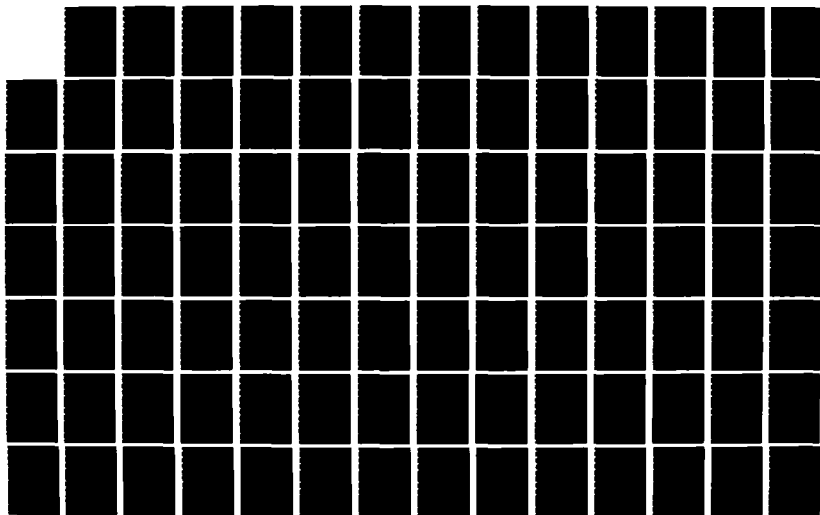
STRUCTURAL DESIGN OF COAL-FUELED POWER PLANT DUCTWORK  
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH  
S P RADER 1986 AFIT/CI/NR-86-153D

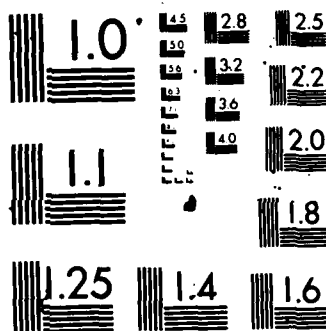
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$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

12. Unit down, maintenance live load top and bottom, snow

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = 0$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lr}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

13. Unit down, maintenance live load bottom

$$w_1 = (q_{D1} + q_{D1} + q_{Di}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = 0$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lr}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

14. Unit down, maintenance live load top, snow

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = 0$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination D)

2.7.2 Normal Operating Conditions, Including Wind or Seismic Effects. Different combinations of the uniformly distributed transverse loads  $w_1$ ,  $w_2$ ,  $w_3$ , and  $w_4$  and the axial loads  $P_1$ ,  $P_2$ ,  $P_3$ , and  $P_4$  are evaluated in order to determine the required stiffener section for each side of the duct under normal operating conditions, including wind or seismic forces. The allowable stiffener stress is increased by 1/3 when these load combinations are applied, per AISC Section 1.5.6. According to ANSI A58.1, Section 2.3.1, wind and seismic effects need not be assumed to act simultaneously.

### 2.7.2.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

$q_{Di}$  - insulation and lagging dead load (psf)

$q_{Dl}$  - duct lining dead load (psf)

$q_{Dn}$  - dead load of side n duct plate (psf)

$$= \gamma_p t_n / 12$$

$q_{La}$  - ash live load (psf)

$q_{Lp}$  - operating pressure, from PDM (psf)

$q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)

$q_{Lv}$  - operating vacuum, from PDM (psf)

$q_S$  - design snow load, from Section 2.3 (psf)

$q_{wn}$  - design wind pressure on side n duct panel, from Section 2.2 (psf)

$s$  - stiffener spacing (in.)

$t_n$  - side n plate thickness (in.)

$w_{Es}$  - uniformly distributed earthquake load to be applied transversely to the side stiffeners, from Section 2.4.2.2 (plf)

$w_{sn}$  - weight per foot of side n stiffener (plf)

$\gamma_p$  - unit weight of duct plate (pcf)

2.7.2.2 Computation. Transverse loads acting inward toward the duct center and axial compressive loads are considered positive. Transverse loads acting outward away from the duct center and axial tensile loads are considered negative. The following 28 transverse load combinations are evaluated.

1. Operating vacuum, ash maintenance live load, snow, wind

$$w_1 = (q_{Dl} + q_{Di} + q_{Lv} + q_{Lr} + q_S + q_{w1}) \frac{s}{12} - w_{s1}$$

$$w_2 = (q_{Lv} - C_{La} q_{La} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{Dl} - q_{Di} + q_{Lv} - q_{La} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} - C_{La} q_{La} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combination A)

2. Operating vacuum, ash, maintenance live load, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = (q_{Lv} - C_{La} q_{La}) \frac{s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} - q_{La}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} - C_{La} q_{La}) \frac{s}{12} + w_{Es}$$

(evaluate with Axial Load Combination A)

3. Operating vacuum, ash, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (q_{Lv} - C_{La} q_{La} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} - q_{La} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} - C_{La} q_{La} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combination A)

4. Operating vacuum, ash, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv}) \frac{s}{12} + w_{s1}$$

$$w_2 = (q_{Lv} - C_{La} q_{La}) \frac{s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} - q_{La}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} - C_{La} q_{La}) \frac{s}{12} + w_{Es}$$

(evaluate with Axial Load Combination A)

5. Operating vacuum, maintenance live load, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{Lr} + q_s + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (q_{Lv} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} + q_{W4}) \frac{s}{12}$$

(evaluate with Axial Load Combination A)

6. Operating vacuum, maintenance live load, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = \frac{q_{Lv}s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv}) \frac{s}{12} - w_{s3}$$

$$w_4 = \frac{q_{Lv}s}{12} + w_{Es}$$

(evaluate with Axial Load Combination A)

7. Operating vacuum, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv} + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (q_{Lv} + q_{W2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (q_{Lv} + q_{W4}) \frac{s}{12}$$

(evaluate with Axial Load Combination A)

8. Operating vacuum, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lv}) \frac{s}{12} + w_{s1}$$

$$w_2 = \frac{q_{Lv}s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{Lv}) \frac{s}{12} - w_{s3}$$

$$w_4 = \frac{q_{Lv}s}{12} + w_{Es}$$

(evaluate with Axial Load Combination A)

9. Operating pressure, ash, maintenance live load, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_s + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} - C_{La} q_{La} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} - C_{La} q_{La} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combinations B and C)

10. Operating pressure, ash, maintenance live load, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_s) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12} + w_{Es}$$

(evaluate with Axial Load Combinations B and C)

11. Operating pressure, ash, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} - C_{La} q_{La} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} - C_{La} q_{La} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combinations B and C)

12. Operating pressure, ash, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} - q_{La}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} - C_{La} q_{La}) \frac{s}{12} + w_{Es}$$

(evaluate with Axial Load Combinations B and C)

13. Operating pressure, maintenance live load, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_S + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combinations B and C)

14. Operating pressure, maintenance live load, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = -\frac{q_{Lp}s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp}) \frac{s}{12} - w_{s3}$$

$$w_4 = -\frac{q_{Lp}s}{12} + w_{Es}$$

(evaluate with Axial Load Combinations B and C)

15. Operating pressure, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp} + q_{w1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-q_{Lp} + q_{w2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp} + q_{w3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-q_{Lp} + q_{w4}) \frac{s}{12}$$

(evaluate with Axial Load Combinations B and C)

16. Operating pressure, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Lp}) \frac{s}{12} + w_{s1}$$

$$w_2 = - \frac{q_{Lp} s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lp}) \frac{s}{12} - w_{s3}$$

$$w_4 = - \frac{q_{Lp} s}{12} + w_{Es}$$

(evaluate with Axial Load Combinations B and C)

17. Unit down, ash, maintenance live load top and bottom, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-C_{La} q_{La} + q_{W2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-C_{La} q_{La} + q_{W4}) \frac{s}{12}$$

(evaluate with Axial Load Combination D)

18. Unit down, ash, maintenance live load top and bottom, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = - \frac{C_{La} q_{La} s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr}) \frac{s}{12} - w_{s3}$$

$$w_4 = - \frac{C_{La} q_{La} s}{12} + w_{Es}$$

(evaluate with Axial Load Combination D)

19. Unit down, ash, maintenance live load bottom, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-C_{La} q_{La} + q_{W2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-C_{La} q_{La} + q_{W4}) \frac{s}{12}$$

(evaluate with Axial Load Combination D)

20. Unit down, ash, maintenance live load bottom, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di}) \frac{s}{12} + w_{s1}$$

$$w_2 = - \frac{C_{La} q_{La} s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} - q_{Lr}) \frac{s}{12} - w_{s3}$$

$$w_4 = - \frac{C_{La} q_{La} s}{12} + w_{Es}$$

(evaluate with Axial Load Combination D)

21. Unit down, ash, maintenance live load top, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = (-C_{La} q_{La} + q_{W2}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = (-C_{La} q_{La} + q_{W4}) \frac{s}{12}$$

(evaluate with Axial Load Combination D)

22. Unit down, ash, maintenance live load top, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = - \frac{C_{La} q_{La} s}{12} - w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{La}) \frac{s}{12} - w_{s3}$$

$$w_4 = - \frac{C_{La} q_{La} s}{12} + w_{Es}$$

(evaluate with Axial Load Combination D)



23. Unit down, maintenance live load top and bottom, snow, wind

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} + q_{Lr} + q_S + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = \frac{q_{W2}s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} - q_{Lr} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = \frac{q_{W4}s}{12}$$

(evaluate with Axial Load Combination D)

24. Unit down, maintenance live load top and bottom, snow, earthquake

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = -w_{Es}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} - q_{Lr}) \frac{s}{12} - w_{s3}$$

$$w_4 = w_{Es}$$

(evaluate with Axial Load Combination D)

25. Unit down, maintenance live load bottom, wind

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = \frac{q_{W2}s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} - q_{Lr} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = \frac{q_{W4}s}{12}$$

(evaluate with Axial Load Combination D)

26. Unit down, maintenance live load bottom, earthquake

$$w_1 = (q_{D1} + q_{Dl} + q_{Di}) \frac{s}{12} + w_{s1}$$

$$w_2 = -w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Lr}) \frac{s}{12} - w_{s3}$$

$$w_4 = w_{Es}$$

(evaluate with Axial Load Combination D)

27. Unit down, maintenance live load top, snow, wind

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S + q_{W1}) \frac{s}{12} + w_{s1}$$

$$w_2 = \frac{q_{W2}s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} + q_{W3}) \frac{s}{12} - w_{s3}$$

$$w_4 = \frac{q_{W4}s}{12}$$

(evaluate with Axial Load Combination D)

28. Unit down, maintenance live load top, snow, earthquake

$$w_1 = (q_{D1} + q_{D1} + q_{Di} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = -w_{Es}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di}) \frac{s}{12} - w_{s3}$$

$$w_4 = w_{Es}$$

(evaluate with Axial Load Combination D)

2.7.3 Excursion Vacuum or Pressure Conditions. Different combinations of the uniformly distributed transverse loads  $w_1$ ,  $w_2$ ,  $w_3$  and  $w_4$ , and the axial loads  $P_1$ ,  $P_2$ ,  $P_3$ , and  $P_4$  are evaluated in order to determine the required stiffener section for each side of the duct under excursion conditions. The allowable stiffener stress is increased by 2/3, up to a maximum equal to the yield stress, under these loading combinations.

#### 2.7.3.1 Required Input.

$C_{La}$  - percent ash live load coefficient, for determination of ash live load on side panels

- $q_{Di}$  - insulation and lagging dead load (psf)
- $q_{Dl}$  - duct lining dead load (psf)
- $q_{Dn}$  - dead load of side n duct plate (psf)  
 $= \gamma_p t_n / 12$
- $q_{La}$  - ash live load (psf)
- $q_{Lr}$  - adjusted maintenance live load, from Section 2.1 (psf)
- $q_S$  - design snow load, from Section 2.3 (psf)
- $q_{Xp}$  - excursion pressure, from PDM (psf)
- $q_{Xv}$  - excursion vacuum, from PDM (psf)
- $s$  - stiffener spacing (in.)
- $t_n$  - side n plate thickness (in.)
- $w_{sn}$  - weight per foot of side n stiffener (plf)
- $\gamma_p$  - unit weight of duct plate (pcf)

2.7.3.2 Computation. Transverse loads acting inward toward the duct center and axial compressive loads are considered positive. Transverse loads acting outward away from the duct center and axial tensile loads are considered negative. The following 8 transverse load combinations are evaluated.

1. Excursion vacuum, ash, maintenance live load, snow

$$w_1 = (q_{Dl} + q_{Di} + q_{Xv} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (q_{Xv} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{Dl} - q_{Di} + q_{Xv} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

2. Excursion vacuum, ash

$$w_1 = (q_{Dl} + q_{Di} + q_{Xv}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (q_{Xv} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{Dl} - q_{Di} + q_{Xv} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

## 3. Excursion vacuum, maintenance live load, snow

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} + q_{Xv} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = \frac{q_{Xv}s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} + q_{Xv}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

## 4. Excursion vacuum

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} + q_{Xv}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = \frac{q_{Xv}s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} + q_{Xv}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combination A)

## 5. Excursion pressure, ash, maintenance live load, snow

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} - q_{Xp} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (-q_{Xp} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} - q_{Xp} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

## 6. Excursion pressure, ash

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} - q_{Xp}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = (-q_{Xp} - C_{La} q_{La}) \frac{s}{12}$$

$$w_3 = (-q_{D3} - q_{Dl} - q_{Di} + q_{Xp} - q_{La}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

## 7. Excursion pressure, maintenance live load, snow

$$w_1 = (q_{D1} + q_{Dl} + q_{Di} - q_{Xp} + q_{Lr} + q_S) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{q_{Xp}s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Xp}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

#### 8. Excursion pressure

$$w_1 = (q_{D1} + q_{D1} + q_{Di} - q_{Xp}) \frac{s}{12} + w_{s1}$$

$$w_2 = w_4 = - \frac{q_{Xp} s}{12}$$

$$w_3 = (-q_{D3} - q_{D1} - q_{Di} - q_{Xp}) \frac{s}{12} - w_{s3}$$

(evaluate with Axial Load Combinations B and C)

### 3. PLATE THICKNESS AND STIFFENER SPACING DETERMINATION

The plate thickness and stiffener spacing for interior panels of the duct section are determined based on nonlinear theory as presented by Timoshenko.<sup>30</sup> Each of the four duct sides is assumed to act independently of the other three sides. Each panel is modeled as one-way plate bending between fixed (no rotation) and held (no in-plane displacement) supports (the stiffeners), with the plate span equal to the stiffener spacing. The procedure is valid for both small and large plate deflections, and includes the effects of both bending and membrane tensile stresses. According to Timoshenko,<sup>31</sup> this approach gives good results for panels with the ratio of stiffener spacing to panel width of less than 2/3. This constraint is met in the vast majority of power plant duct work configurations.

Due to fabrication considerations, the plate thicknesses in the end panels must be the same as for the adjacent interior panels. The required plate boundary condition for use of the nonlinear theory (fixed and held edges), however, is not satisfied in the end panels. End stiffeners with adequate torsional and minor axis rigidity to reasonably approximate the nonlinear theory boundary condition requirement would be impracticably heavy. Therefore, the stiffener spacings for the end panels are based on linear theory in which the supports are assumed to be unrestrained in the plane of the plate. This results in closer stiffener spacings for the end panels.

Calculations indicate that the linear theory approach should be used to determine the stiffener spacing from the end of the duct section inward for a distance equal to one half the width of the duct cross section (for top and bottom duct panels) or one half the height of the duct cross section (for side duct panels). If this design guideline is used, the maximum plate deflection in the first interior panel with the greater stiffener spacing (based on nonlinear theory) may exceed the theoretical maximum deflection (calculated using the nonlinear approach and assuming rigidly held edges) by as much as 50 percent. If this increased maximum deflection in the first interior panel designed according to nonlinear theory is unacceptable, the linear theory is used to determine the stiffener spacing for a distance inward from the end of the duct section equal to the width of the duct cross section (for top and bottom panels) or the height of the duct cross section (for side panels).

### 3.1 Required Input.

$D_{p,allow}$  - ratio of stiffener spacing to allowable plate deflection

$E_p$  - plate modulus of elasticity (ksi)

$\nu$  - Poisson's ratio for the plate

### 3.2 Interior Panels.

Using a trial value for plate thickness and stiffener spacing,  $u$  is determined, using the bisection algorithm, from Equation (15) in Theory of Plates and Shells:

$$\frac{(20.736 \times 10^9) E_p^2 t^8}{(1-\nu^2)^2 q s^8} = -\frac{81}{16u^7 \tanh u} - \frac{27}{16u^6 \sinh^2 u} + \frac{27}{4u^8} + \frac{9}{8u^6}$$

where

$E_p$  = plate modulus of elasticity (ksi)

$t$  = plate thickness (in.)

$v$  = Poisson's ratio for the plate  
 $q$  = uniformly distributed load, as determined in Section 2.5  
 (psf)

$s$  = stiffener spacing (in.)

$$u = \sqrt{\frac{S_p s^2}{4D}} \quad (\text{Equation (5), Theory of Plates and Shells})$$

$S_p$  = membrane force in the plate (k/in.)

$D$  = flexural rigidity of the plate (k-in.)

$$= \frac{E_p t^3}{12(1-v^2)}$$

The constant tensile stress (membrane stress) in the plate is

$$\sigma_1 = \frac{E_p u^2}{3(1-v^2)} \left(\frac{t}{s}\right)^2 \quad (\text{Equation (16), Theory of Plates and Shells})$$

The maximum bending stress in the plate, which occurs in the extreme fibers at the fixed supports (stiffeners), is:

$$\sigma_2 = \frac{q}{288 \times 10^3} \left(\frac{s}{t}\right)^2 \psi_1(u) \quad (\text{Equation (17), Theory of Plates and Shells})$$

where

$$\psi_1(u) = \frac{3(u - \tanh u)}{u^2 \tanh u} \quad (\text{Equation (13), Theory of Plates and Shells})$$

The maximum total stress is

$$\sigma_{p,\max} = \sigma_1 + \sigma_2$$

where

$\sigma_{p,\max}$  = maximum plate stress (ksi)

$\sigma_1$  = plate membrane stress (ksi)

$\sigma_2$  = maximum plate bending stress (ksi)

Note: Humphreys<sup>32</sup> presents the following alternate equation for determining maximum stress in the plate which may be used for quick hand calculation of the maximum stress. This expression ranges from about 2.5 percent unconservative to 10 percent conservative (for heavy loading) compared to Timoshenko.

$$\sigma_{p,\max} = E_p^{0.23} w^{0.77} \left(\frac{s}{t}\right)^{1.08} \quad \text{for } \delta_{p,\max} \geq t/2$$

where

$E_p$  = plate modulus of elasticity (psi)

$w$  = uniformly distributed load (psi)

$s$  = stiffener spacing (in.)

$t$  = plate thickness (in.)

The maximum plate deflection (at center span; midway between the stiffeners) is

$$\delta_{p,\max} = \frac{qs^4}{55.3 \times 10^6 D} f_1(u) \quad \text{(Equation (18), Theory of Plates and Shells)}$$

where

$$f_1(u) = \frac{24}{u^4} \left( \frac{u^2}{2} + \frac{u}{\sinh u} - \frac{u}{\tanh u} \right)$$

The above method for solving for maximum plate stresses and deflections of interior panels is practical in a design environment only when used in a computer program.

**3.3 End Panels.** The plate thickness is the same as that for the adjacent interior panel. The maximum stress and deflection are calculated using linear theory and assuming that the plate is simply supported along one side and fixed along the other. The stiffeners are assumed to provide no restraint in the plane of the plate.

The maximum total stress is

$$\sigma_{p,\max} = \frac{qs^2}{192000 t^2}$$

where

$\sigma_{p,\max}$  = maximum plate stress (ksi)

$q$  = uniformly distributed load, as determined in Section 2.5 (psf)

$s$  = stiffener spacing (in.)

$t$  = plate thickness (in.)



The maximum plate deflection is

$$\delta_{p,\max} = \frac{qs^4}{26.64 \times 10^6 D}$$

where

$\delta_{p,\max}$  = maximum plate deflection (in.)

D = flexural rigidity of the plate, as calculated in Section 3.2 (k-in.)

3.4 Design Criteria. The design criteria for plate stress and deflection are as given in Sections 3.4.1, 3.4.2 and 3.4.3.

3.4.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.

3.4.1.1 Interior Panel Stress Criterion. The plate thickness and stiffener spacing for interior panels are selected such that the following interaction equation is satisfied.

$$\frac{\sigma_1}{0.60 F_{yp}} + \frac{\sigma_2}{0.75 F_{yp}} \leq 1.0$$

where

$\sigma_1$  = plate membrane (tension) stress, from Section 3.2 (ksi)

$\sigma_2$  = maximum plate bending stress, from Section 3.2 (ksi)

$F_{yp}$  = plate yield stress (ksi)

3.4.1.2 End Panel Stress Criterion. The plate thickness and stiffener spacing for end panels are selected such that the following criterion is satisfied.

$$\sigma_{p,\max} \leq 0.75 F_{yp}$$

where

$\sigma_{p,\max}$  = maximum plate stress, from Section 3.3 (ksi)

3.4.1.3 Interior and End Panel Deflection Criteria. The maximum allowable plate deflection of  $\frac{s}{100}$  has been used in the past by ductwork designers at Black & Veatch with satisfactory results. A more restrictive value for allowable plate deflection may be required due to such factors as manufacturer-specified maximum deflections for certain duct lining materials.

3.4.2 Normal Operating Conditions, Including Wind or Seismic Effects. Allowable stresses may be increased by 1/3 above the values otherwise provided when wind or seismic effects are included in the design loading, according to AISC Section 1.5.6. Sections 3.4.2.1 and 3.4.2.2 reflect the increased allowable stress.

3.4.2.1 Interior Panel Stress Criterion. The plate thickness and stiffener spacing for interior panels are selected such that the following interaction equation is satisfied.

$$\frac{\sigma_1}{0.80 F_{yp}} + \frac{\sigma_2}{F_{yp}} \leq 1.0$$

3.4.2.2 End Panel Stress Criterion. The plate thickness and stiffener spacing for end panels are selected such that the following criterion is satisfied.

$$\sigma_{p,max} \leq F_{yp}$$

3.4.2.3 Interior and End Panel Deflection Criteria. No maximum deflection is specified for this loading, unless required by the client or duct lining manufacturer.

3.4.3 Excursion Vacuum or Pressure Conditions.

3.4.3.1 Interior Panel Stress Criterion. The plate thickness and stiffener spacing for interior panels are selected such that the following criterion is satisfied.

$$\sigma_1 + \sigma_2 \leq F_{yp}$$

3.4.3.2 End Panel Stress Criterion. The plate thickness and stiffener spacing for end panels are selected such that the following criterion is satisfied.

$$\sigma_{p,max} \leq F_{yp}$$

3.4.3.3 Interior and End Panel Deflection Criteria. No maximum deflection is specified for this loading, unless required by the client or duct lining manufacturer.

3.5 Corrosion Allowance. If needed, a corrosion allowance is added to the duct thickness. The additional thickness is not considered when calculating strength and stiffness properties of the plate, but is included in the plate dead load. The normal corrosion allowance is between 1/16 and 1/8 inch.

#### 4. PINNED-END STIFFENER DESIGN

Each stiffener is considered independently, as a pinned-end beam-column with length equal to the duct width or height, as applicable, unless internal bracing is provided to reduce the unbraced length. The top and bottom stiffeners are designed to resist combined loading from transverse forces and the axial force due to internal pressures or vacuums. The side stiffeners are designed to resist the combined loading from transverse forces and axial forces due to tension field action and internal pressures or vacuums. Stiffeners on all four sides are designed to have the same nominal depth due to insulation and lagging installation requirements. Stiffener spacings may vary for different sides of the same duct section. However, stiffener spacings for all sides of the duct are selected to be even multiples of the minimum stiffener spacing for that section of duct.

Equal moduli of elasticity for the duct plate and stiffeners are assumed in the following design procedure. If there is a significant difference between the two, the designer should calculate stresses and deflections based on a transformed section, as described by Timoshenko.<sup>33</sup> Differing plate and stiffener yield stresses are accommodated in the following design procedure.

4.1 Effective Section Properties Determination. A trial section is selected and the effective moment of inertia and section modulus for the combined section and effective plate are calculated. The effective plate width (portion of the plate adjacent to the stiffener which can be considered to act with the stiffener in resisting bending and axial forces) is

$$b_{en} = 1.5 t \sqrt{\frac{E_p}{F_{yp}}}$$

where

$b_{en}$  = effective plate width to be used in conjunction with stiffener  $n$  (in.)

$t$  = plate thickness (in.)

$E_p$  = plate modulus of elasticity (ksi)

$F_{yp}$  = plate yield stress (ksi)

This represents a conservative adjustment to the equation developed by E. E. Sechler.<sup>34</sup> This equation is used by the U.S. Army Corps of Engineers to specify the effective flange width of skinplate adjacent to vertical tee section stiffeners on spillway tainter gates.<sup>35</sup>

The procedure given in Sections 4.1.1 and 4.1.2 is used to find the effective section modulus and moment of inertia of the stiffener and plate assembly. Nomenclature is as shown in Figure 6.

#### 4.1.1 WT Sections.

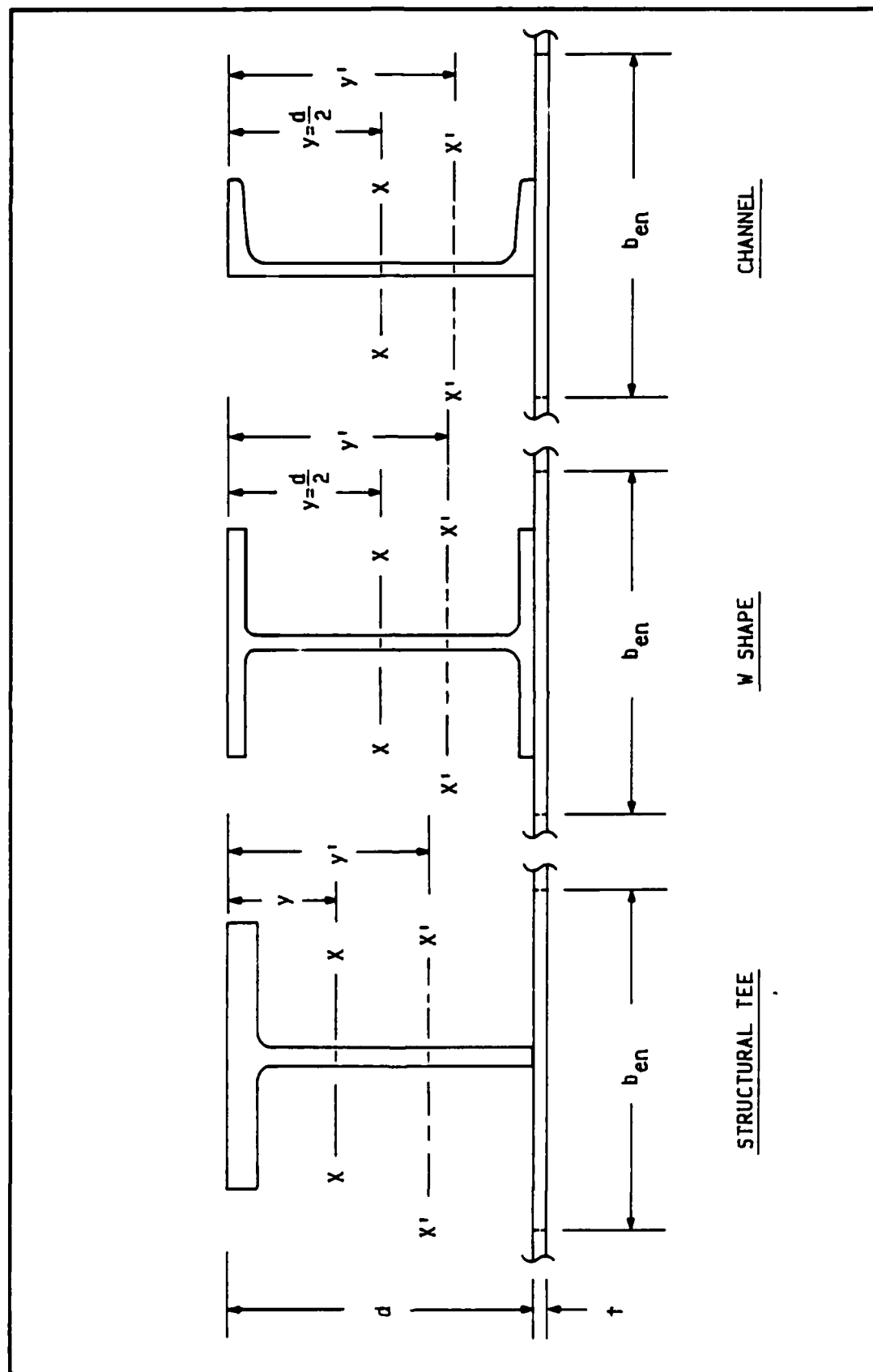


FIGURE 6. COMBINED STIFFENER AND EFFECTIVE PLATE

#### 4.1.1.1 Required Input.

$y$  = distance to centroidal axis of stiffener (in.)

$A_s$  = cross-sectional area of stiffener (in.<sup>2</sup>)

$I_s$  = moment of inertia of stiffener (in.<sup>4</sup>)

$t$  = plate thickness (in.)

$d$  = depth of member (in.)

$E_p$  = modulus of elasticity of plate (ksi)

$F_{yp}$  = plate yield stress (ksi)

#### 4.1.1.2 Effective Cross-Sectional Area, $A_e$ .

$$A_e = A_s + b_{en} t$$

#### 4.1.1.3 Distance to Effective Centroidal Axis, $y'$ .

$$y' = \frac{A_s y + b_{en} t (d + t/2)}{A_e}$$

where

$$b_{en} = 1.5 t \sqrt{\frac{E_p}{F_{yp}}}$$

#### 4.1.1.4 Effective Moment of Inertia of Combined Stiffener and Effective Plate, $I_e$ .

$$I_e = I_s + A_s (y' - y)^2 + \frac{b_{en} t^3}{12} + b_{en} t (d + \frac{t}{2} - y')^2$$

#### 4.1.1.5 Effective Radius of Gyration of Combined Stiffener and Effective Plate, $r_e$ .

$$r_e = \sqrt{\frac{I_e}{A_e}}$$

#### 4.1.2 W and Channel Sections.

##### 4.1.2.1 Required Input.

$d$  = depth of member (in.)

$t$  = plate thickness (in.)

$A_s$  = cross-sectional area of stiffener (in.<sup>2</sup>)

$I_s$  = moment of inertia of stiffener (in.<sup>4</sup>)

$E_p$  = modulus of elasticity of the plate (ksi)

$F_{yp}$  = plate yield stress (ksi)

4.1.2.2 Computation. The distance  $y = d/2$  is calculated. Then  $A_e$ ,  $y'$ ,  $I_e$ , and  $r_e$  are calculated as shown in Sections 4.1.1.2, 4.1.1.3, 4.1.1.4, and 4.1.1.5.

4.2 Transverse Loading. The transverse loading on the combined stiffener and adjacent effective plate is determined as shown in Section 2.6.1. Positive transverse loads act inward toward the duct center.

4.2.1 Maximum Bending Stress. Maximum bending stresses in the trial stiffener section and in the effective portion of the plate adjacent to the stiffener due to transverse loads are calculated as follows.

##### 4.2.1.1 Normal Operating Conditions, Excluding Wind and Seismic Forces.

###### 4.2.1.1.1 Positive Loading.

$$f_{bst+} = \frac{M_{\max} (d-y')}{I_e} = \frac{w_{n+} L_n^2 (12 \text{ in./ft.})(d-y')}{8 I_e (10^3 \text{ lb/k})}$$

$$f_{bst+} = \frac{0.0015 w_{n+} L_n^2 (d-y')}{I_e}$$

$$f_{bsc+} = \frac{0.0015 w_{n+} L_n^2 y'}{I_e}$$

$$f_{bp+} = \frac{0.0015 w_{n+} L_n^2 (d+t_n - y')}{I_e}$$

where

$f_{bst+}$  = maximum stiffener tensile bending stress under positive loading (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress under positive loading (ksi)

$f_{bp+}$  = maximum effective plate tensile bending stress under positive loading (ksi)

$M_{max}$  = maximum stiffener moment (k-in.)

$d$  = depth of stiffener section (in.)

$y'$  = distance from extreme exterior fiber to centroidal axis of combined stiffener and effective plate, from Section 4.1 (in.)

$w_{n+}$  = positive uniformly distributed load on side  $n$  due to normal operation, excluding wind and seismic forces, from Section 2.6.1.1 (plf)

$L_n$  = width of side  $n$  duct panel (ft.)

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate, from Section 4.1 (in.<sup>4</sup>)

$t_n$  = side  $n$  plate thickness (in.)

#### 4.2.1.1.2 Negative Loading.

$$f_{bst-} = \frac{0.0015 w_{n-} L_n^2 y'}{I_e}$$

$$f_{bsc-} = \frac{0.0015 w_{n-} L_n^2 (d-y')}{I_e}$$

$$f_{bp-} = \frac{0.0015 w_{n-} L_n^2 (d+t_n - y')}{I_e}$$

wh re



$f_{bst-}$  = maximum stiffener tensile bending stress under negative loading (ksi)

$f_{bsc-}$  = maximum stiffener compressive bending stress under negative loading (ksi)

$f_{bp-}$  = maximum effective plate compressive bending stress under negative loading (ksi)

4.2.1.2 Normal Operating Conditions, Including Wind or Seismic Forces. The procedure detailed in Section 4.2.1.1 is followed, where  $w_{n+}$  and  $w_{n-}$  are as determined in Section 2.6.1.2.

4.2.1.3 Excursion Vacuum or Pressure Conditions. The procedure detailed in Section 4.2.1.1 is followed, where  $w_{n+}$  and  $w_{n-}$  are as determined in Section 2.6.1.3.

4.2.2 Allowable Bending Stress. The allowable bending stresses in the absence of axial forces are computed for the trial stiffener section and the adjacent effective plate. When channel sections are used as stiffeners, Sections 4.2.2.1.3 and 4.2.2.2.2 only apply.

4.2.2.1 Positive Loading. Positive transverse loads act inward toward the duct center causing compression in the exterior flange of the stiffener and tension in the effective plate.

4.2.2.1.1 Adaptation of AISC Section 1.5.1.4.1.

$$F_{bst+} = F_{bsc+} = 0.66 F_{ys}$$

$$F_{bp+} = 0.66 F_{yp}$$

- If:
1. The stiffener is continuously welded to the duct plate.
  2. The width-thickness ratio of the exterior stiffener flange does not exceed  $65/\sqrt{F_{ys}}$ .

3. The depth-thickness ratio of the web does not exceed  $(640/\sqrt{F_{ys}})(1-3.74 f_{an+}/F_{ys})$  when  $f_{an+}/F_{ys} \leq 0.16$  nor  $257/\sqrt{F_{ys}}$  when  $f_{an+}/F_{ys} > 0.16$ , where  $f_{an+}$  is calculated as shown in Section 4.3.1.
4. The laterally unsupported length of the exterior stiffener flange does not exceed:

$$\frac{76b_f}{\sqrt{F_{ys}}} \text{ nor } \frac{20,000}{(d'/A_f) F_{ys}}$$

where

$F_{bst+}$  = allowable stiffener tensile bending stress due to positive loads in the absence of axial force (ksi)

$F_{bsc+}$  = allowable stiffener compressive bending stress due to positive loads in the absence of axial force (ksi)

$F_{bp+}$  = allowable effective plate bending stress due to positive loads in the absence of axial force (ksi)

$F_{ys}$  = stiffener yield stress (ksi)

$F_{yp}$  = plate yield stress (ksi)

$b_f$  = stiffener flange width (in.)

$d'$  = depth of stiffener section plus plate thickness (in.)

$A_f$  = area of exterior flange (in.<sup>2</sup>)

4.2.2.1.2 Adaptation of AISC Section 1.5.1.4.2. For plate-stiffener combinations which satisfy the requirements of AISC 1.5.1.4.1 above, except that  $65/\sqrt{F_{ys}} < b_f/2t_f < 95/\sqrt{F_{ys}}$

$$F_{bst+} = F_{bsc+} = F_{ys} \left[ 0.79 - 0.002 \left( \frac{b_f}{2t_f} \right) \sqrt{F_{ys}} \right] \quad (\text{AISC Equation (1.5-5a)})$$

$$F_{bp+} = F_{bst+} \left( \frac{F_{yp}}{F_{ys}} \right)$$

where  $t_f$  = exterior stiffener flange thickness (in.)

4.2.2.1.3 Adaptation of AISC Section 1.5.1.4.5. For channels and for plate-stiffener combinations not covered in Sections 4.2.2.1.1

or 4.2.2.1.2, the provisions of Sections 4.2.2.1.3.1 and 4.2.2.1.3.2 apply.

4.2.2.1.3.1 Tension. (from AISC Section 1.5.1.4.5.1)

$$F_{bst+} = 0.60 F_{ys}$$

$$F_{bp+} = 0.60 F_{yp}$$

4.2.2.1.3.2 Compression. (from AISC Section 1.5.1.4.5.2)

From AISC Section 1.5.1.4.5.2a:

If the width-thickness ratio of exterior (unstiffened) stiffener flange is not greater than  $95/\sqrt{F_{ys}}$ , the allowable compressive bending stress is the larger value computed by AISC Formulas (1.5-6a) or (1.5-6b) and (1.5-7) as shown below. For channels, AISC Formula (1.5-7) only is used.

$$\text{When } \sqrt{\frac{102 \times 10^3}{F_{ys}}} \leq \frac{l_n}{r_t} \leq \sqrt{\frac{510 \times 10^3}{F_{ys}}},$$

$$F_{bsc+} = \left[ \frac{2}{3} - \frac{F_{ys} (l_n/r_t)^2}{1,530 \times 10^3} \right] F_{ys} \leq 0.60 F_{ys}$$

(AISC Equation (1.5-6a))

$$\text{When } \frac{l_n}{r_t} \geq \sqrt{\frac{510 \times 10^3}{F_{ys}}},$$

$$F_{bsc+} = \frac{170 \times 10^3}{(l_n/r_t)^2} \leq 0.60 F_{ys}$$

(AISC Equation (1.5-6b))

or

$$F_{bsc+} = \frac{12 \times 10^3}{l_n d'/A_f} \leq 0.60 F_{ys}$$

(AISC Equation (1.5-7))

where

$l_n$  = maximum distance between stiffener cross sections braced against twist or lateral displacement of the exterior flange, for side  $n$  (in.)

$r_t$  = radius of gyration of a section comprising the exterior flange of the stiffener plus 1/3 of the web area on the exterior side

of the stiffener neutral axis, taken about an axis in the plane of the web (in.)

(Note: In the three AISC equations, (1.5-6a), (1.5-6b), and (1.5-7), shown above,  $C_b$  is taken as unity.)

From AISC Section 1.5.1.4.5.2b:

For plate-stiffener combinations not covered in AISC Section 1.5.1.4.5.2a above,

$$F_{bsc+} = 0.60 F_{ys},$$

- if: 1. The width-thickness ratio of exterior (unstiffened) stiffener flanges is not greater than  $95/\sqrt{F_{ys}}$ .
2.  $l_n \leq 76 b_f/\sqrt{F_{ys}}$

4.2.2.2 Negative Loading. Negative transverse loads act outward away from the duct center causing compression in the effective portion of the plate and tension in the exterior stiffener flange. The compression flange of the plate-stiffener combination can be considered to have continuous lateral support under negative loading.

Since the ratio of stiffener spacing to plate thickness will always exceed  $253/\sqrt{F_{yp}}$ , the provisions of AISC Appendix C govern the stiffener design under negative loading, as specified in AISC Section 1.9.2.2. However, Section C3 of AISC Appendix C states that  $b_e/t$ , the ratio of the reduced effective width of a stiffened compression element (the duct plate) to the plate thickness, need not be taken less than the applicable value permitted in Section 1.9.2.2 (which is  $253/\sqrt{F_{yp}}$  for this case). It can be shown that  $b_e/t$  will not exceed  $253/\sqrt{F_{yp}}$  when the effective width of the plate is limited to  $b_e = 1.5t\sqrt{E_p/F_{yp}}$ , as is specified in Section 4.1 herein.

Due to the savings in computational effort, the value of  $b_e$  is conservatively taken as  $1.5t\sqrt{E_p/F_{yp}}$  when designing stiffeners under all negative loads, and AISC Equation (C3-2), which might allow for a greater effective plate width, is not applied. Using this approach, the allowable bending stresses under negative loading are calculated as follows.

$$F_{bst-} = F_{bsc-} = 0.60 F_{ys}$$

$$F_{bp-} = 0.60 F_{yp}$$

4.3 Axial Loading. The axial loading on the combined stiffener and adjacent effective plate is determined as shown in Section 2.6.2.

4.3.1 Maximum Axial Stress. Axial compressive stresses are considered positive. Axial tensile stresses are considered negative.

4.3.1.1 Normal Operating Conditions.

4.3.1.1.1 Positive Loading. Vacuums and vertical stiffener axial forces associated with tension field action are considered positive loads, causing axial compressive stresses in the stiffener and adjacent effective plate.

$$f_{a1+} = \frac{P_{v1}}{A_e} \left( \frac{1 \text{ k}}{1,000 \text{ lb}} \right) = \frac{P_{v1}}{1,000 A_e}$$

$$f_{a2+} = \frac{P_s + P_{v2}}{1,000 A_e}$$

$$f_{a3+} = \frac{P_{v3}}{1,000 A_e}$$

$$f_{a4+} = \frac{P_s + P_{v4}}{1,000 A_e}$$

where

$f_{an+}$  = maximum axial compressive stress in stiffener and adjacent effective plate on side n (ksi)

$P_{vn}$  = axial compressive force in stiffener n due to normal operating vacuum, as calculated in Section 2.6.2.1.1 (lb)

$P_s$  = axial compressive force in vertical stiffener due to tension field action, as calculated in Section 2.6.2.2

$A_e$  = area of combined stiffener and effective plate, from Section 4.1 (in.<sup>2</sup>)

4.3.1.1.2 Negative Loading. Pressures are considered negative loads, causing axial tensile stresses in the stiffener and adjacent effective plate.

$$f_{a1-} = \frac{P_{p1}}{1,000 A_e}$$

$$f_{a2-} = \frac{P_s}{1,000 A_e} \text{ (axial tension due to internal pressure is ignored)}$$

$$f_{a3-} = \frac{P_{p3}}{1,000 A_e}$$

$$f_{a4-} = \frac{P_s}{1,000 A_e} \text{ (axial tension due to internal pressure is ignored)}$$

where

$f_{an-}$  = maximum axial stress due to negative loading in stiffener and adjacent effective plate on side n (ksi)

$P_{pn}$  = axial tensile force in stiffener n due to normal operating pressure, as calculated in Section 2.6.2.1.1 (lb)

4.3.1.2 Excursion Conditions. The equations given in Section 4.3.1.1 are used, where  $P_{vn}$  and  $P_{pn}$  are as calculated in Section 2.6.2.1.2.

4.3.2 Allowable Axial Compressive Stress. The allowable axial compressive stress in the absence of bending moment is computed for the trial stiffener section and adjacent effective plate. Each stiffener is assumed to have an unbraced length equal to the width or height of the duct cross section, as applicable. The effective length factor is taken as unity.

4.3.2.1 Adaptation of AISC Section 1.5.1.3.1. If the width-thickness ratio of the exterior (unstiffened) stiffener flange does not exceed  $95/\sqrt{F_{ys}}$ , and  $12 L_n/r_e \leq C_c$ , then

$$F_a = \frac{\left[ 1 - \frac{(12 L_n/r_e)^2}{2 C_c^2} \right] F_{ys}}{\frac{5}{3} + \frac{3(12 L_n/r_e)}{8 C_c} - \frac{(12 L_n/r_e)^3}{8 C_c^3}}$$

where

$F_a$  = allowable axial compressive stiffener stress in the absence of bending moment (ksi)

$L_n$  = length of stiffener  $n$  (ft.)

$r_e$  = effective radius of gyration of combined stiffener and effective plate, from Section 4.1 (in.)

$F_{ys}$  = stiffener yield stress (ksi)

$$C_c = \sqrt{\frac{2\pi^2 E_s}{F_{ys}}}$$

$E_s$  = stiffener modulus of elasticity (ksi)

4.3.2.2 Adaptation of AISC Section 1.5.1.3.2. For stiffener sections not covered in Section 4.3.2.1,

$$F_a = \frac{12\pi^2 E_s}{23 (12 L_n/r_e)^2}$$

4.4 Trial Section Determination. For simplicity in design and fabrication, all intermediate stiffeners on any one side of a section of ductwork are of identical size, and are designed to resist the axial forces due to tension field action and/or internal pressure or vacuum, and the lateral loading,  $w_n$ , appropriate for the loading case. All intermediate stiffeners on all sides of a section of ductwork are designed to have the same nominal depth. The intermediate stiffeners

are sized to satisfy the requirements of Sections 4.4.1, 4.4.2, and 4.4.3 following.

4.4.1 Normal Operating Conditions, Excluding Wind and Seismic Forces.

4.4.1.1 Positive Loading.

If  $\frac{f_{an+}}{F_a} \leq 0.15$ , use AISC Formula (1.6-2):

$$\frac{f_{an+}}{F_a} + \frac{f_{bsc+}}{F_{bsc+}} \leq 1.0$$

where

$f_{an+}$  = maximum axial compressive stress in stiffener and adjacent effective plate on side n, for normal operation, as calculated in Section 4.3.1.1.1 (ksi)

$F_a$  = allowable axial compressive stiffener stress in the absence of bending moment, as calculated in Section 4.3.2 (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress under positive loading, for normal operation excluding wind and seismic forces, as determined in Section 4.2.1.1.1 (ksi)

$F_{bsc+}$  = allowable stiffener compressive bending stress due to positive loads in the absence of axial force, as determined in Section 4.2.2.1 (ksi)

If  $\frac{f_{an+}}{F_a} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{f_{an+}}{F_a} + \frac{C_m f_{bsc+}}{\left(1 - \frac{f_{an+}}{F'_e}\right) F_{bsc+}} \leq 1.0$$

(Buckling is possible only in the direction normal to the duct plate.)



where

$$C_m = 1.0$$

(AISC Section 1.6.1, Case 3b)

$$F'_e = \frac{12 \pi^2 E_s}{23 (K l_b / r_b)^2}$$

where

$$K = 1.0 \text{ (pinned at duct corners)}$$

$$r_b = \sqrt{\frac{I_e}{A_e}}$$

$$l_b = L_n (12 \text{ in./ft.})$$

Substituting:

$$F'_e = \frac{12 \pi^2 E_s I_e}{23 (144 L_n^2 A_e)} = \frac{\pi^2 E_s I_e}{276 L_n^2 A_e}$$

In the above expression:

$A_e$  = area of combined stiffener and adjacent effective plate, from Section 4.1 (in.<sup>2</sup>)

$E_s$  = stiffener modulus of elasticity (ksi)

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate, as determined in Section 4.1 (in.<sup>4</sup>)

$L_n$  = height of side n duct panel (ft.)

Since  $F_a$  will not exceed  $0.60 F_{ys}$  (see Section 4.3.2) and  $C_m = 1.0$  (AISC Section 1.6.1, Case 3b), it is apparent that AISC Equation (1.6-1a) will always control, when compared to AISC Equation (1.6-1b). Therefore, Equation (1.6-1b) is not evaluated during the design process.

#### 4.4.1.2 Negative Loading.

4.4.1.2.1 Top and Bottom Stiffeners. The top and bottom stiffeners are subjected to combined axial tension and bending stresses under negative loading conditions. Therefore, the provisions of AISC

Section 1.6.2 apply. The top and bottom stiffeners are selected to satisfy the following requirements:

$$\frac{|f_{an-}|}{0.60 F_{ys}} + \frac{|f_{bst-}|}{F_{bst-}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$|f_{bsc-}| \leq F_{bsc-}$$

where

$f_{an-}$  = maximum axial stress due to negative loading in stiffener and adjacent effective plate on side n, for normal operation, as determined in Section 4.3.1.1.2 (ksi)

$F_{ys}$  = stiffener yield stress (ksi)

$f_{bst-}$  = maximum stiffener tensile bending stress under negative loading, for normal operation excluding wind and seismic forces, as determined in Section 4.2.1.1.2 (ksi)

$F_{bst-}$  = allowable stiffener tensile bending stress due to negative loads in the absence of axial force, as determined in Section 4.2.2.2 (ksi)

$f_{bsc-}$  = maximum stiffener compressive bending stress under negative loading, for normal operation excluding wind and seismic forces, as determined in Section 4.2.1.1.2 (ksi)

$F_{bsc-}$  = allowable stiffener compressive bending stress due to negative loads in the absence of axial force, as determined in Section 4.2.2.2 (ksi)

4.4.1.2.2 Side (Vertical) Stiffeners. The side stiffeners are subjected to combined axial compression due to tension field action and bending stresses under negative loading conditions. As noted in Section 4.3.1.1.2, the axial tension due to internal pressure is ignored, so that the axial compression is conservatively taken as the full value due to tension field action.

$$\text{If } \frac{f_{an-}}{F_a} \leq 0.15, \text{ use AISC Formula (1.6-2):}$$

$$\frac{f_{an-}}{F_a} + \frac{|f_{bsc-}|}{F_{bsc-}} \leq 1.0$$

If  $\frac{f_{an-}}{F_a} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{f_{an-}}{F_a} + \frac{|f_{bsc-}|}{\left(1 - \frac{276 L_n^2 A_e f_{an-}}{\pi^2 E_s I_e}\right) F_{bsc-}} \leq 1.0$$

4.4.2 Normal Operating Conditions, Including Wind or Seismic Forces. According to AISC Sections 1.5.6 and 1.6.1, if the design lateral load on the stiffener includes wind or seismic forces, the allowable stresses  $F_a$ ,  $F_{bst-}$ ,  $F_{bsc+}$ ,  $F_{bsc-}$ ,  $0.60 F_{ys}$ , and  $F'_e$  may be increased by 1/3. This adjustment is made in the following forms of AISC Equations (1.6-2) and (1.6-1a).

4.4.2.1 Positive Loading.

If  $\frac{3f_{an+}}{4F_a} \leq 0.15$ , use AISC Formula (1.6-2):

$$\frac{3f_{an+}}{4F_a} + \frac{3f_{bsc+}}{4F_{bsc+}} \leq 1.0$$

If  $\frac{3f_{an+}}{4F_a} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{3f_{an+}}{4F_a} + \frac{3f_{bsc+}}{4 \left(1 - \frac{207 L_n^2 A_e f_{an+}}{\pi^2 E_s I_e}\right) F_{bsc+}} \leq 1.0$$

where

$f_{an+}$  = maximum axial compressive stress in stiffener and adjacent effective plate on side n, for normal operation, as determined in Section 4.3.1.1.1 (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress under positive loading, for normal operation including wind or seismic forces, as determined in Section 4.2.1.2 (ksi)

#### 4.4.2.2 Negative Loading.

4.4.2.2.1 Top and Bottom Stiffeners. The top and bottom stiffeners are selected to satisfy the following requirements:

$$\frac{|f_{an-}|}{0.80 F_{ys}} + \frac{3|f_{bst-}|}{4F_{bst-}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$|f_{bsc-}| \leq \frac{4}{3} F_{bsc-}$$

where

$f_{an-}$  = maximum axial stress due to negative loading in stiffener and adjacent effective plate on side n, for normal operation, as determined in Section 4.3.1.1.2 (ksi)

$f_{bst-}$  = maximum stiffener tensile bending stress under negative loading, for normal operation including wind or seismic forces, as determined in Section 4.2.1.2 (ksi)

$f_{bsc-}$  = maximum stiffener compressive bending stress under negative loading, for normal operation including wind or seismic forces, as determined in Section 4.2.1.2 (ksi)

#### 4.4.2.2.2 Side (Vertical) Stiffeners.

If  $\frac{3f_{an-}}{4F_a} \leq 0.15$ , use AISC Formula (1.6-2):

$$\frac{3f_{an-}}{4F_a} + \frac{3|f_{bsc-}|}{4F_{bsc-}} \leq 1.0$$

If  $\frac{3f_{an-}}{4F_a} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{3f_{an-}}{4F_a} + \frac{3|f_{bsc-}|}{4 \left( 1 - \frac{207 L_n^2 A_e f_{an-}}{\pi^2 E_s I_e} \right) F_{bsc-}} \leq 1.0$$

4.4.3 Excursion Vacuum or Pressure Conditions. For this loading case, the allowable stresses  $F_a$ ,  $F_{bst-}$ ,  $F_{bsc+}$ ,  $F_{bsc-}$ , and  $0.60 F_y$ , are increased by 2/3 or set equal to the yield stress, whichever is less.  $F'_e$  is increased by 23/12. These adjustments are included in the following forms of AISC Equations (1.6-1a), (1.6-1b) and (1.6-2).

#### 4.4.3.1 Positive Loading.

If  $\frac{3f_{an+}}{5F_a} \leq 0.15$ , use AISC Formula (1.6-2):

$$\frac{3f_{an+}}{5F_a} + \frac{3f_{bsc+}}{5F_{bsc+}} \leq 1.0$$

If  $\frac{3f_{an+}}{5F_a} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{3f_{an+}}{5F_a} + \frac{f_{bsc+}}{\left( 1 - \frac{144 L_n^2 A_e f_{an+}}{\pi^2 E_s I_e} \right) F'_{bsc+}} \leq 1.0$$

where

$f_{an+}$  = maximum axial compressive stress in stiffener and adjacent effective plate on side n, for excursion vacuum conditions, as determined in Section 4.3.1.2 (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress under positive loading, for excursion vacuum conditions, as determined in Section 4.2.1.3 (ksi)

$F'_{bsc+} = 5/3 F_{bsc+} \leq F_{ys}$ , where  $F_{bsc+}$  is the allowable stiffener compressive bending stress due to positive loads in the absence of axial force, as calculated in Section 4.2.2.1 (ksi)

#### 4.4.3.2 Negative Loading.

4.4.3.2.1 Top and Bottom Stiffeners. The top and bottom stiffeners are selected to satisfy the following requirements:

$$\frac{|f_{an-}|}{F_{ys}} + \frac{|f_{bst-}|}{F_{ys}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$|f_{bsc-}| \leq F_{ys}$$

where

$f_{an-}$  = maximum axial stress due to negative loading in stiffener and adjacent effective plate on side n, for excursion pressure conditions, as determined in Section 4.3.1.2 (ksi)

$f_{bst-}$  = maximum stiffener tensile bending stress under negative loading, for excursion conditions, as determined in Section 4.2.1.3 (ksi)

$f_{bsc-}$  = maximum stiffener compressive bending stress under negative loading, for excursion pressure conditions, as determined in Section 4.2.1.3 (ksi)

#### 4.4.3.2.2 Side (Vertical) Stiffeners.

If  $\frac{f_{an-}}{F_{ys}} \leq 0.15$ , use AISC Formula (1.6-2):

$$\frac{f_{an-}}{F_{ys}} + \frac{|f_{bsc-}|}{F_{ys}} \leq 1.0$$

If  $\frac{f_{an-}}{F_{ys}} > 0.15$ , use AISC Formula (1.6-1a):

$$\frac{f_{an-}}{F_{ys}} + \frac{|f_{bsc-}|}{\left(1 - \frac{144 L_n^2 A_e f_{an-}}{\pi^2 E_s I_e}\right) F_{ys}} \leq 1.0$$

4.5 Maximum Plate Stress. If the plate yield stress,  $F_{yp}$ , is less than the stiffener yield stress,  $F_{ys}$ , the maximum combined axial

and bending stresses in the effective portion of the plate adjacent to the stiffener are checked.

#### 4.5.1 Normal Operating Conditions, Excluding Wind and Seismic Forces.

4.5.1.1 Positive Loading. Positive loads act inward toward the center of the duct and cause tensile bending stresses in the effective portion of the plate adjacent to the stiffener. However, the operating vacuum (a positive load, since it tends to deflect the stiffeners toward the center of the duct) also causes an axial compressive stress in the effective portion of the plate. The axial compressive stress tends to offset the tensile bending stress. A conservative approach is used, in that each stress is considered separately and at its full value. The following requirements must be satisfied:

$$f_{bp+} \leq F_{bp+}$$

$$f_{an+} \leq 0.60 F_{yp}$$

where

$f_{bp+}$  = maximum effective plate tensile bending stress under positive loading, for normal operating conditions excluding wind and seismic forces, as determined in Section 4.2.1.1.1 (ksi)

$F_{bp+}$  = allowable effective plate bending stress due to positive loads in the absence of axial force, as determined in Section 4.2.2.1 (ksi)

$f_{an+}$  = maximum axial compressive stress in effective plate on side n, for normal operation, as determined in Section 4.3.1.1.1 (ksi)

$F_{yp}$  = plate yield stress (ksi)

#### 4.5.1.2 Negative Loading.

4.5.1.2.1 Top and Bottom Stiffeners. The same considerations as discussed in Section 4.5.1.1 for positive loading apply to the top and bottom stiffeners under negative loading. The following requirements must be satisfied:

$$\begin{aligned} |f_{bp-}| &\leq F_{bp-} \\ |f_{an-}| &\leq 0.60 F_{yp} \end{aligned}$$

where

$f_{bp-}$  = maximum effective plate compressive bending stress under negative loading, for normal operating conditions excluding wind and seismic forces, as determined in Section 4.2.1.1.2 (ksi)

$F_{bp-}$  = allowable effective plate bending stress due to negative loads in the absence of axial force, as determined in Section 4.2.2.2 (ksi)

$f_{an-}$  = maximum axial stress due to negative loading in the effective plate on side n, for normal operation, as determined in Section 4.3.1.1.2 (ksi)

4.5.1.2.2 Side (Vertical) Stiffeners. The effective portion of the plate adjacent to the stiffener is subjected to both the compressive bending stress due to the negative transverse loads and the axial compressive stress due to tension field action. The axial tensile stress due to the internal pressure is ignored, as noted in Section 4.3.1.1.2. The following interaction equation must be satisfied:

$$\frac{f_{an-}}{0.60 F_{yp}} + \frac{|f_{bp-}|}{F_{bp-}} \leq 1.0$$

4.5.2 Normal Operating Conditions, Including Wind or Seismic Forces.

4.5.2.1 Positive Loading.

$$\begin{aligned} f_{bp+} &\leq \frac{4}{3} F_{bp+} \\ f_{an+} &\leq 0.80 F_{yp} \end{aligned}$$

where

$f_{bp+}$  = maximum effective plate tensile bending stress under positive loading, for normal operating conditions including wind or seismic forces, as determined in Section 4.2.1.2 (ksi)



$f_{an+}$  = maximum axial compressive stress in effective plate on side n, for normal operation, as determined in Section 4.3.1.1.1 (ksi)

#### 4.5.2.2 Negative Loading.

##### 4.5.2.2.1 Top and Bottom Stiffeners.

$$|f_{bp-}| \leq 4/3 F_{bp-}$$

$$|f_{an-}| \leq 0.80 F_{yp}$$

where

$f_{bp-}$  = maximum effective plate compressive bending stress under negative loading, for normal operating conditions including wind or seismic forces, as determined in Section 4.2.1.2 (ksi)

$f_{an-}$  = maximum axial stress due to negative loading in effective plate on side n, for normal operation, as determined in Section 4.3.1.1.2 (ksi)

##### 4.5.2.2.2 Side (Vertical) Stiffeners.

$$\frac{f_{an-}}{0.80F_{yp}} + \frac{3|f_{bp-}|}{4F_{bp-}} \leq 1.0$$

#### 4.5.3 Excursion Conditions.

##### 4.5.3.1 Positive Loading.

$$f_{bp+} \leq F_{yp}$$

$$f_{an+} \leq F_{yp}$$

where

$f_{bp+}$  = maximum effective plate tensile bending stress under positive loading, for excursion conditions, as determined in Section 4.2.1.3 (ksi)

$f_{an+}$  = maximum axial compressive stress in effective plate on side n, for excursion conditions, as determined in Section 4.3.1.2 (ksi)

#### 4.5.3.2 Negative Loading.

##### 4.5.3.2.1 Top and Bottom Stiffeners.

$$\begin{aligned} |f_{bp-}| &\leq F_{yp} \\ |f_{an-}| &\leq F_{yp} \end{aligned}$$

where

$f_{bp-}$  = maximum effective plate compressive bending stress under negative loading, for excursion conditions, as determined in Section 4.2.1.3 (ksi)

$f_{an-}$  = maximum axial stress due to negative loading in effective plate on side n, for excursion conditions, as determined in Section 4.3.1.2 (ksi)

##### 4.5.3.2.2 Side (Vertical) Stiffeners.

$$\frac{f_{an-}}{F_{yp}} + \frac{|f_{bp-}|}{F_{yp}} \leq 1.0$$

4.6 Maximum Deflection. Each stiffener is selected such that the maximum deflection of the combined stiffener and adjacent effective plate is limited to the following:

$$\delta_{s,max} \leq \delta_{s,allow}$$

where

$\delta_{s,max}$  = maximum stiffener deflection, as calculated in Sections 4.6.1 and 4.6.2 (in.)

$\delta_{s,allow}$  = allowable stiffener deflection (in.)

$$= L_n (12 \text{ in./ft.}) / D_{s,allow}$$

$L_n$  = stiffener length on side n (ft.)

$D_{s,allow}$  = ratio of stiffener length to allowable stiffener deflection, as appropriate for the loading case.

##### 4.6.1 Simultaneous Axial Compression and Transverse Loading.

Maximum deflection of the combined stiffener and adjacent effective plate under simultaneous axial compression and transverse loading is

calculated. The equation for maximum deflection, from Roark and Young, Formulas for Stress and Strain,<sup>36</sup> is

$$\delta_{s,max} = \frac{w}{12 k^2 P_n} \left[ \frac{1}{\cos(6kL_n)} - 18k^2 L_n^2 - 1 \right]$$

where

$w$  = uniformly distributed transverse load, as specified in Section 4.6.1.1, 4.6.1.2 or 4.6.1.3 (plf)

$$k = \left[ \frac{P_n}{1,000 E_s I_e} \right]^{1/2}$$

$P_n$  = axial compressive force in stiffener  $n$ , as specified in Section 4.6.1.1, 4.6.1.2 or 4.6.1.3 (lb)

$E_s$  = stiffener modulus of elasticity

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate, from Section 4.1 (in.<sup>4</sup>)

#### 4.6.1.1 Normal Operating Conditions, Excluding Wind and Seismic Forces.

$w = w_{n+}$ , as determined in Section 2.6.1.1

$P_n = P_{vn}$ , as determined in Sections 2.6.2.1.1, for top and bottom stiffeners

$P_n = P_{vn} + P_s$ , as determined in Sections 2.6.2.1.1 and 2.6.2.2, respectively, for side (vertical) stiffeners

#### 4.6.1.2 Normal Operating Conditions, Including Wind or Seismic Forces.

$w = w_{n+}$ , as determined in Section 2.6.1.2

$P_n = P_{vn}$ , as determined in Section 2.6.2.1.1, for top and bottom stiffeners

$P_n = P_{vn} + P_s$ , as determined in Sections 2.6.2.1.1 and 2.6.2.2, respectively, for side (vertical) stiffeners

#### 4.6.1.3 Excursion Conditions.

$w = w_{n+}$ , as determined in Section 2.6.1.3

$P_n = P_{vn}$ , as determined in Section 2.6.2.1.2, for top and bottom stiffeners

$P_n = P_{vn} + P_s$ , as determined in Sections 2.6.2.1.2 and 2.6.2.2, respectively, for side (vertical) stiffeners

4.6.2 Transverse Loading Only. In addition to the deflection due to simultaneous axial compression and transverse loading checked in Section 4.6.1, the maximum deflection of the bottom stiffener and adjacent effective plate due to transverse negative loads only is calculated. In this case, the associated axial tensile force in the bottom stiffener, which tends to reduce the maximum deflection, is ignored.

$$\begin{aligned}\delta_{s,max} &= \frac{5wL_n^4}{384 E_s I_e} \left( \frac{1 \text{ k}}{1,000 \text{ lb}} \right) \left( \frac{1,728 \text{ in.}^3}{1 \text{ ft}^3} \right) \\ &= \frac{.0225wL_n^4}{E_s I_e}\end{aligned}$$

where

$w = w_{3-}$ , as calculated in Sections 2.6.1.1, 2.6.1.2 or 2.6.1.3, as appropriate for the loading case

4.7 Plate Girder Stiffener Checks. The side (vertical) stiffeners are checked using the AISC plate girder stiffener requirements.

4.7.1 Moment of Inertia Requirement. The AISC Section 1.10.5.4 stiffener moment of inertia requirement is checked.

If  $I_w < \left[ \frac{12 L_n - L_{Yt} - L_{Yb}}{50} \right]^4$ , then a stiffener section with a larger moment of inertia is selected,

where

$I_w$  = moment of inertia of the vertical stiffener with reference to an axis in the plane of the adjacent duct plate (in.<sup>4</sup>)

$$= I_s + A_s [(d-y) + t/2]^2$$

$I_s$  = moment of inertia of the vertical stiffener (in.<sup>4</sup>)

$A_s$  = stiffener cross-sectional area (in.<sup>2</sup>)

$d$  = stiffener section depth (in.)

$y$  = distance to centroidal axis of stiffener (in.)

$t$  = adjacent plate thickness (in.)

$L_n$  = height of side panel  $n$ , where  $n = 2$  or  $4$  (ft.)

$L_{Yt}, L_{Yb}$  = length of top and bottom corner angle legs parallel to the vertical axis, respectively (in.).

4.7.2 Gross Area Requirement. The AISC Section 1.10.5.4 stiffener gross area requirement is checked.

$$A_s \geq \frac{1 - C_v}{2} \left[ \alpha - \frac{\alpha^2}{\sqrt{1 + \alpha^2}} \right] \frac{F_{yp}}{F_{ys}} (12L_n - L_{Yt} - L_{Yb}) \beta t$$

where

$$C_v = \frac{45,000k}{F_{yp} \left( \frac{12L_n - L_{Yt} - L_{Yb}}{t_n} \right)^2} \text{ when } C_v < 0.8$$

$$= \frac{190}{\left( \frac{12L_n - L_{Yt} - L_{Yb}}{t_n} \right)} \sqrt{\frac{k}{F_{yp}}} \text{ when } C_v > 0.8$$

$$k = 4.00 + \frac{5.34}{\alpha^2}$$

$$\alpha = \frac{s}{12L_n - L_{Yt} - L_{Yb}}$$

$s$  = stiffener spacing (in.)

$F_{yp}$  = plate yield stress (ksi)

$F_{ys}$  = stiffener yield stress (ksi)

$$\beta = 2.4 \frac{f_v}{F_v}$$

$f_v$  = average web shear stress (ksi)

$$= \frac{w_g L}{4,000 (12L_n - L_{Yt} - L_{Yb}) t}$$

$w_g$  = uniformly distributed load on duct section due to gravity loads as calculated in Section 2.6.2.2 (plf)

$L$  = duct span (ft.)

$F_v$  = allowable web shear stress (ksi)

$$= \frac{F_{yp}}{2.89} (C_v) \leq 0.40 F_{yp} \quad (\text{AISC Equation (1.10-1)})$$

The value of  $F_v$  calculated from AISC Equation (1.10-1) is more conservative than that calculated from AISC Equation (1.10-2), but is used here because the provisions of AISC Section 1.10.5.3 regarding the required  $a/h$  ratio may not always be satisfied, as required for use of Equation (1.10-2).

#### 5. RIGID FRAME STIFFENER DESIGN

The stiffeners on the four sides of the duct are joined by moment-resisting connections at the duct corners, and analyzed as a rigid frame. The top and bottom stiffeners are designed to resist combined transverse loading and axial loading from internal pressures or vacuums. The side stiffeners are designed to resist simultaneous transverse loading and axial loading due to internal pressures or vacuums and tension field action in the duct side panels. Stiffeners on all four sides of the duct are designed to have the same nominal depth due to insulation and lagging installation requirements. Stiffener spacings must be equal for all four sides of the duct.

In the following design procedure it is assumed that the moduli of elasticity of the duct plate and stiffeners are equal. If there is a significant difference between the two, stresses and deflections should be calculated based on a transformed section as described by Timoshenko.<sup>37</sup> Differing plate and stiffener yield stresses are accommodated in the following design procedure.

5.1 Transverse Loading. The transverse loading on the combined stiffener and adjacent effective plate is determined as shown in Section 2.7.

5.1.1 Maximum Bending Moments. Trial stiffener sections for each of the four sides are selected and the respective effective section properties are calculated using the method given in Section 4.1.

The maximum stiffener moments for each of the four sides are calculated due to the loading combinations specified in Section 2.7. Nomenclature is as shown in Figure 7.

#### 5.1.1.1 Stiffener End Moment Calculation.

General Slope-Deflection Equation:

$$M_{\text{near end}} = M_{0, \text{ near end}} + \frac{2EI}{l} (2\phi_{\text{near end}} + \phi_{\text{far end}} - 3R)$$

where

$M_0$  = stiffener fixed-end moment

$E$  = modulus of elasticity

$I$  = stiffener moment of inertia

$l$  = length of stiffener

$\phi$  = joint rotation

$R$  = stiffener axis rotation

Since the design loading is symmetrical about both major axes of the duct, there is no stiffener axis rotation. Therefore,  $R = 0$  in all cases.

The fixed-end moments for the stiffeners are of the form  $wl^2/12$ .

$$M_{0n} = \frac{w_n L_n^2}{12} \left( \frac{12 \text{ in.}}{1 \text{ ft.}} \right) \left( \frac{1 \text{ kip}}{1,000 \text{ lb}} \right)$$

where

$M_{0n}$  = stiffener n fixed-end moment (k-in.)

$w_n$  = uniformly distributed transverse load on stiffener n, from Section 2.7, as appropriate for the loading case (plf)

$L_n$  = length of stiffener n (ft.)

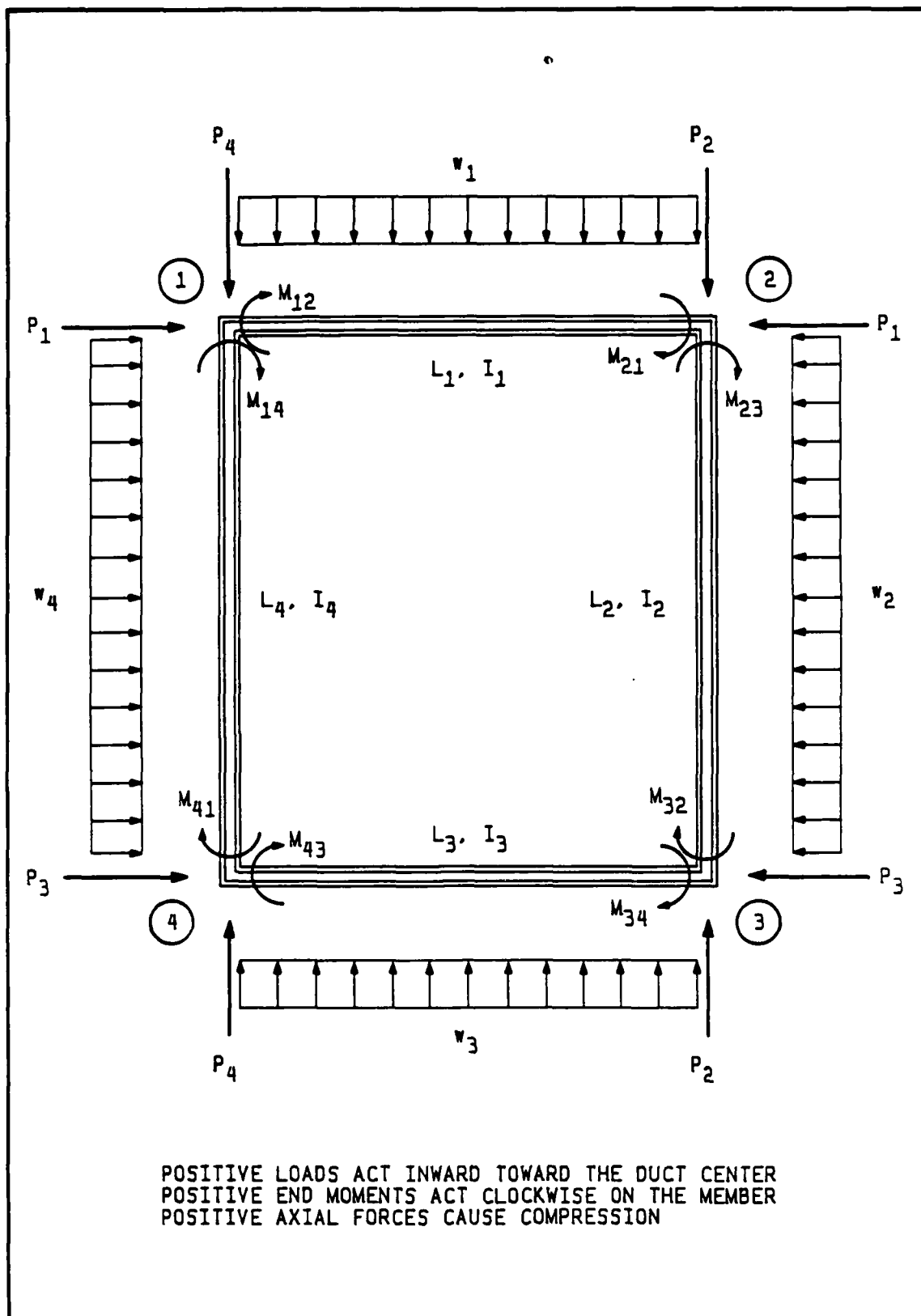


FIGURE 7. STIFFENER RIGID FRAME



The slope-deflection equations for the eight stiffener end moments are:

$$M_{12} = -M_{01} + \frac{E_s I_{e1}}{6 L_1} (2\phi_1 + \phi_2)$$

$$M_{21} = +M_{01} + \frac{E_s I_{e1}}{6 L_1} (2\phi_2 + \phi_1)$$

$$M_{23} = -M_{02} + \frac{E_s I_{e2}}{6 L_2} (2\phi_2 + \phi_3)$$

$$M_{32} = +M_{02} + \frac{E_s I_{e2}}{6 L_2} (2\phi_3 + \phi_2)$$

$$M_{34} = -M_{03} + \frac{E_s I_{e3}}{6 L_3} (2\phi_3 + \phi_4)$$

$$M_{43} = +M_{03} + \frac{E_s I_{e3}}{6 L_3} (2\phi_4 + \phi_3)$$

$$M_{41} = -M_{04} + \frac{E_s I_{e4}}{6 L_4} (2\phi_4 + \phi_1)$$

$$M_{14} = +M_{04} + \frac{E_s I_{e4}}{6 L_4} (2\phi_1 + \phi_4)$$

In the above equations, positive stiffener end moments act clockwise on the stiffener.

The joint equations are:

$$\text{Joint 1: } M_{14} + M_{12} = 0$$

$$2 \left( \frac{I_{e4}}{L_4} + \frac{I_{e1}}{L_1} \right) \phi_1 + \frac{I_{e1}}{L_1} \phi_2 + 0 + \frac{I_{e4}}{L_4} \phi_4 = \frac{6(M_{01} - M_{04})}{E_s}$$

$$\text{Joint 2: } M_{21} + M_{23} = 0$$

$$\frac{I_{e1}}{L_1} \phi_1 + 2 \left( \frac{I_{e1}}{L_1} + \frac{I_{e2}}{L_2} \right) \phi_2 + \frac{I_{e2}}{L_2} \phi_3 + 0 = \frac{6(M_{02} - M_{01})}{E_s}$$

$$\text{Joint 3: } M_{32} + M_{34} = 0$$

$$0 + \frac{I_{e2}}{L_2} \phi_2 + 2 \left( \frac{I_{e2}}{L_2} + \frac{I_{e3}}{L_3} \right) \phi_3 + \frac{I_{e3}}{L_3} \phi_4 = \frac{6(M_{03} - M_{02})}{E_s}$$

Joint 4:  $M_{43} + M_{41} = 0$

$$\frac{I_{e4}}{L_4} \phi_1 + 0 + \frac{I_{e3}}{L_3} \phi_3 + 2 \left( \frac{I_{e3}}{L_3} + \frac{I_{e4}}{L_4} \right) \phi_4 = \frac{6(M_{04} - M_{03})}{E_s}$$

Solving joint equations 1 through 4 simultaneously for  $\phi_1$  through  $\phi_4$ :

Let  $[A] =$

$2 \left( \frac{I_{e4}}{L_4} + \frac{I_{e1}}{L_1} \right)$	$\frac{I_{e1}}{L_1}$	0	$\frac{I_{e4}}{L_4}$
$\frac{I_{e1}}{L_1}$	$2 \left( \frac{I_{e1}}{L_1} + \frac{I_{e2}}{L_2} \right)$	$\frac{I_{e2}}{L_2}$	0
0	$\frac{I_{e2}}{L_2}$	$2 \left( \frac{I_{e2}}{L_2} + \frac{I_{e3}}{L_3} \right)$	$\frac{I_{e3}}{L_3}$
$\frac{I_{e4}}{L_4}$	0	$\frac{I_{e3}}{L_3}$	$2 \left( \frac{I_{e3}}{L_3} + \frac{I_{e4}}{L_4} \right)$

Let  $[B] =$

$\phi_1$
$\phi_2$
$\phi_3$
$\phi_4$

Let  $[C] =$

$\frac{6}{E_s}$	$M_{01} - M_{04}$
	$M_{02} - M_{01}$
	$M_{03} - M_{02}$
	$M_{04} - M_{03}$

Then  $[A] \times [B] = [C]$  and  $[B] = [A]^{-1} \times [C]$ .

$\phi_1$ ,  $\phi_2$ ,  $\phi_3$ , and  $\phi_4$  are substituted back into the slope-deflection equations to find the eight stiffener end moments.

The maximum positive and negative moments for each of the four stiffeners are solved for as shown in Section 5.1.1.2.

### 5.1.1.2 Maximum Positive and Negative Moments.

From statics:

$$M_x = M_{ij} + \left( \frac{3w_n L_n}{500} - \frac{M_{ij} + M_{ji}}{L_n} \right) x - \frac{3w_n x^2}{500}$$

where

$M_x$  = stiffener moment at distance  $x$  clockwise from joint  $i$  (k-in.). A positive value of  $M_x$  indicates that the fibers on the inside of the frame are in tension.

$x$  = distance clockwise from joint  $i$  (ft.)

$M_{ij}$  = stiffener end moment at joint  $i$ , as solved for in Section 5.1.1 (k-in.)

$M_{ji}$  = stiffener end moment at joint  $j$ , where joint  $j$  is the joint adjacent to and clockwise from joint  $i$ , as solved for in Section 5.1.1 (k-in.)

$M_x$  is evaluated at specified intervals along the stiffener and the maximum positive and maximum negative moments in the stiffener,  $M_{max+}$  and  $M_{max-}$ , are determined.

5.1.2 Maximum Bending Stresses. Maximum stresses due to bending moments in the stiffeners and adjacent effective plate are calculated.

$$f_{bst+} = \frac{M_{max+} (d-y')}{I_e}$$

$$f_{bsc+} = \frac{M_{max+} y'}{I_e}$$

$$f_{bp+} = \frac{M_{max+} (d+t-y')}{I_e}$$

$$f_{bst-} = \frac{M_{max-} y'}{I_e}$$

$$f_{bsc-} = \frac{M_{max-} (d-y')}{I_e}$$

$$f_{bp-} = \frac{M_{max-} (d+t-y')}{I_e}$$

where

$f_{bst+}$  = maximum stiffener tensile bending stress due to positive moment (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress due to positive moment (ksi)

$f_{bp+}$  = maximum effective plate tensile bending stress due to positive moment (ksi)

$f_{bst-}$  = maximum stiffener tensile bending stress due to negative moment (ksi)

$f_{bsc-}$  = maximum stiffener compressive bending stress due to negative moment (ksi)

$f_{bp-}$  = maximum effective plate compressive bending stress due to negative moment (ksi)

$M_{max+}$  = maximum positive moment in the stiffener, as calculated in Section 5.1.1.2 (k-in.)

$M_{max-}$  = maximum negative moment in the stiffener, as calculated in Section 5.1.1.2 (k-in.)

$d$  = depth of stiffener section (in.)

$y'$  = distance to effective centroidal axis, as calculated in Section 4.1 (in.)

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate, as calculated in Section 4.1 (in.<sup>4</sup>)

$t$  = adjacent plate thickness (in.)

5.1.3 Allowable Bending Stresses. The allowable bending stresses  $F_{bst+}$ ,  $F_{bp+}$ ,  $F_{bst-}$ ,  $F_{bsc-}$ , and  $F_{bp-}$  are calculated using the procedure given in Section 4.2.2.

The allowable bending stress  $F_{bsc+}$  is calculated using the procedure given in Section 4.2.2.1.3.2, with the following modification:

If  $l_n/12 < L_n$  (intermediate compression flange bracing provided):

$$C_b = 1.0$$

(There is no change to the equations given in Section 4.2.2.1.3.2 for this case.)

If  $l_n/12 = L_n$  (no intermediate compression flange bracing), when applying AISC Equations (1.5-6a), (1.5-6b), and (1.5-7),

$$C_b = 1.75 + 1.05 (M_1/M_2) + 0.3 (M_1/M_2)^2 \leq 2.3$$

where  $M_1$  is the smaller absolute value and  $M_2$  is the larger absolute value stiffener end moment. Clockwise end moments are positive and counterclockwise end moments are negative. If the bending moment at any point between the ends of the stiffener is greater than both stiffener end moments,  $C_b = 1.0$ .

5.2 Axial Loading. The axial loading on the combined stiffener and adjacent effective plate is determined as shown in Section 2.7.

5.2.1 Maximum Axial Stress. Axial compressive stresses are positive. Axial tensile stresses are negative.

$$f_{an} = \frac{P_n}{A_e} \left( \frac{1k}{1,000 \text{ lb}} \right)$$

where

$f_{an}$  = maximum axial compressive or tensile stress in stiffener and adjacent effective plate on side  $n$  (ksi)

$P_n$  = axial force in stiffener  $n$ , as calculated in Section 2.7 (lb)

$A_e$  = area of combined stiffener and adjacent effective plate, as calculated in Section 4.1 (in.<sup>2</sup>).

5.2.2 Allowable Axial Compressive Stress. The allowable axial compressive stress in the absence of bending moment for the trial stiffener section and adjacent effective plate is determined as shown in Section 4.3.2, except that the effective length factor is taken as 1.2 (from AISC Table C1.8.1, Case (c)).

5.3 Trial Section Determination. For simplicity in design and fabrication, all intermediate stiffeners on any one side of a section of ductwork are of identical size, and are designed to resist the axial forces due to tension field action and/or internal pressure or vacuum, and the transverse loading appropriate for the loading case.

All intermediate stiffeners on all sides of a section of ductwork are designed to have the same nominal depth.

### 5.3.1 Simultaneous Axial Compression and Transverse Loading.

The trial stiffener section must satisfy the provisions of Sections 5.3.1.1, 5.3.1.2, and 5.3.1.3 following for all loading cases in which the stiffener is subjected to simultaneous axial compression and transverse loading.

#### 5.3.1.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.

5.3.1.1.1 Negligible Axial Stress. If  $\frac{f_{an}}{F_a} \leq 0.15$ , AISC Formula (1.6-2) is used.

##### 5.3.1.1.1.1 Maximum Positive Moment.

$$\frac{f_{an}}{F_a} + \frac{f_{bsc+}}{F_{bsc+}} \leq 1.0$$

where

$f_{an}$  = maximum axial compressive stress in stiffener and adjacent effective plate on side n, as determined in Section 5.2.1 (ksi)

$f_a$  = allowable axial compressive stiffener stress in the absence of bending moment, as determined in Section 5.2.2 (ksi)

$f_{bsc+}$  = maximum stiffener compressive bending stress due to maximum positive moment, for normal operation excluding wind and seismic forces, from Section 5.1.2 (ksi)

$F_{bsc+}$  = allowable stiffener compressive bending stress due to positive moment in the absence of axial force, from Section 5.1.3 (ksi).

##### 5.3.1.1.1.2 Maximum Negative Moment.

$$\frac{f_{an}}{F_a} + \frac{|f_{bsc-}|}{F_{bsc-}} \leq 1.0$$

where

$f_{bsc-}$  = maximum stiffener compressive bending stress due to maximum negative moment, for normal operation excluding wind and seismic forces from Section 5.1.2 (ksi).

$F_{bsc-}$  = allowable stiffener compressive bending stress due to negative moment in the absence of axial force from Section 5.1.3 (ksi).

5.3.1.1.2 Significant Axial Stress. If  $\frac{f_{an}}{F} > 0.15$ , the stiffener section is checked using AISC Formulas (1.6-1a)<sup>a</sup> and (1.6-1b).

5.3.1.1.2.1 Maximum Positive Moment.

$$\frac{f_{an}}{F_a} + \frac{C_m f_{bsc+}}{\left(1 - \frac{f_{an}}{F'_e}\right) F_{bsc+}} \leq 1.0 \quad (\text{AISC Equation (1.6-1a)})$$

(Buckling is possible only in the direction normal to the duct plate.)

where

(AISC Section 1.6.1, Case 1)

$$C_m = 0.85$$

$$F'_e = \frac{12\pi^2 E_s}{23 (Kl_b/r_b)^2}$$

$K = 1.2$  (AISC Table C1.8.1, Case (c), which represents a conservative idealization of the side stiffeners.)

$$r_b = \sqrt{\frac{I_e}{A_e}}$$

$$l_b = L_n \text{ (12 in./ft.)}$$

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate, from Section 4.1 (in.<sup>4</sup>)

$A_e$  = area of combined stiffener and effective plate, as calculated in Section 4.1 (in.<sup>2</sup>)

$$L_n = \text{length of stiffener } n \text{ (ft.)}$$

### 5.3.1.1.2.2 Maximum Negative Moment.

$$\frac{f_{an}}{F_a} + \frac{.85 f_{bsc-}}{\left(1 - \frac{f_{an}}{F'_e}\right) F_{bsc-}} \leq 1.0 \quad (\text{AISC Equation (1.6-1a)})$$

5.3.1.1.2.3 Stiffener End Checks. The stiffener section is checked using AISC Formula (1.6-1b).

At Joint i:

If  $M_{ij}$  is positive (clockwise):

$$\frac{f_{an}}{0.60 F_{ys}} + \frac{M_{ij} y'}{I_e F_{bsc+}} \leq 1.0$$

If  $M_{ij}$  is negative (counterclockwise):

$$\frac{f_{an}}{0.60 F_{ys}} - \frac{M_{ij} (d - y')}{I_e F_{bsc-}} \leq 1.0$$

At Joint j:

If  $M_{ji}$  is positive (clockwise):

$$\frac{f_{an}}{0.60 F_{ys}} + \frac{M_{ji} (d - y')}{I_e F_{bsc-}} \leq 1.0$$

If  $M_{ji}$  is negative (counterclockwise):

$$\frac{f_{an}}{0.60 F_{ys}} - \frac{M_{ji} y'}{I_e F_{bsc+}} \leq 1.0$$

where

$M_{ij}$ ,  $M_{ji}$  = stiffener end moments at Joints i and j, respectively, due to normal operation excluding wind and seismic forces, where end moments are calculated using procedure given in Section 5.1.1.1. (Joint j is the joint adjacent to and clockwise from Joint i.) (k-in.)

5.3.1.2 Normal Operating Conditions, Including Wind or Seismic Forces. Allowable stresses  $F_a$ ,  $F_{bsc+}$ ,  $F_{bsc-}$ ,  $0.60 F_{ys}$ , and  $F'_e$  are increased by 1/3 in accordance with AISC Sections 1.5.6 and 1.6.1. The following forms of the AISC formulas reflect this change.



5.3.1.2.1 Negligible Axial Stress. If  $\frac{3 f_{an}}{4 F_a} \leq 0.15$ , AISC Formula (1.6-2) is used.

5.3.1.2.1.1 Maximum Positive Moment.

$$\frac{3 f_{an}}{4 F_a} + \frac{3 f_{bsc+}}{4 F_{bsc+}} \leq 1.0$$

where

$f_{bsc+}$  = maximum stiffener compressive bending stress due to maximum positive moment, for normal operation including wind or seismic forces, from Section 5.1.2 (ksi)

5.3.1.2.1.2 Maximum Negative Moment.

$$\frac{3 f_{an}}{4 F_a} + \frac{3 |f_{bsc-}|}{4 F_{bsc-}} \leq 1.0$$

where

$f_{bsc-}$  = maximum stiffener compressive bending stress due to maximum negative moment, for normal operation including wind or seismic forces, from Section 5.1.2 (ksi)

5.3.1.2.2 Significant Axial Stress. If  $\frac{3 f_{an}}{4 F_a} > 0.15$ , the stiffener section is checked using AISC Formulas (1.6-1a) and (1.6-1b).

5.3.1.2.2.1 Maximum Positive Moment.

$$\frac{3 f_{an}}{4 F_a} + \frac{0.6375 f_{bsc+}}{\left(1 - \frac{3 f_{an}}{4 F'_e}\right) F_{bsc+}} \leq 1.0$$

5.3.1.2.2.2 Maximum Negative Moment.

$$\frac{3 f_{an}}{4 F_a} + \frac{0.6375 |f_{bsc-}|}{\left(1 - \frac{3 f_{an}}{4 F'_e}\right) F_{bsc-}} \leq 1.0$$

5.3.1.2.2.3 Stiffener End Checks. The stiffener section is checked using AISC Formula (1.6-1b).

At Joint i:

If  $M_{ij}$  is positive (clockwise):

$$\frac{f_{an}}{0.80 F_{ys}} + \frac{3 M_{ij} y'}{4 I_e F_{bsc+}} \leq 1.0$$

If  $M_{ij}$  is negative (counterclockwise):

$$\frac{f_{an}}{0.80 F_{ys}} - \frac{3 M_{ij} (d - y')}{4 I_e F_{bsc-}} \leq 1.0$$

At Joint j:

If  $M_{ji}$  is positive (clockwise):

$$\frac{f_{an}}{0.80 F_{ys}} + \frac{3 M_{ji} (d - y')}{4 I_e F_{bsc-}} \leq 1.0$$

If  $M_{ji}$  is negative (counterclockwise):

$$\frac{f_{an}}{0.80 F_{ys}} - \frac{3 M_{ji} y'}{4 I_e F_{bsc+}} \leq 1.0$$

where

$M_{ij}$ ,  $M_{ji}$  = stiffener end moments at Joints i and j, respectively, due to normal operation including wind or seismic forces, where end moments are calculated using procedure given in Section 5.1.1.1. (Joint j is the joint adjacent to and clockwise from Joint i.) (k-in.)

5.3.1.3 Excursion Vacuum or Pressure Conditions. For this loading case, the allowable stresses  $F_a$ ,  $F_{bsc+}$ ,  $F_{bsc-}$  and  $0.60 F_{ys}$  are increased by 2/3 or set equal to the yield stress, whichever is less.  $F'_e$  is increased by 23/12. These adjustments are included in the following forms of AISC Equations (1.6-1a), (1.6-1b) and (1.6-2).

5.3.1.3.1 Negligible Axial Stress. If  $\frac{3 f_{an}}{5 F_a} \leq 0.15$ , AISC Formula (1.6-2) is used.

#### 5.3.1.3.1.1 Maximum Positive Moment.

$$\frac{3 f_{an}}{5 F_a} + \frac{f_{bsc+}}{F'_{bsc+}} \leq 1.0$$

where

$f_{bsc+}$  = maximum stiffener compressive bending stress due to maximum positive moment, for excursion conditions, from Section 5.1.2 (ksi)

$$F'_{bsc+} = 5/3 F_{bsc+} \leq F_{ys}$$

#### 5.3.1.3.1.2 Maximum Negative Moment.

$$\frac{3 f_{an}}{5 F_a} + \frac{f_{bsc-}}{F_{ys}} \leq 1.0$$

where

$f_{bsc-}$  = maximum stiffener compressive bending stress due to maximum negative moment, for excursion conditions, from Section 5.1.2 (ksi)

5.3.1.3.2 Significant Axial Stress. If  $\frac{3 f_{an}}{5 F_a} > 0.15$ , the stiffener section is checked using AISC Formulas (1.6-1a) and (1.6-1b).

#### 5.3.1.3.2.1 Maximum Positive Moment.

$$\frac{3 f_{an}}{5 F_a} + \frac{0.85 f_{bsc+}}{\left(1 - \frac{12 f_{an}}{23 F'_e}\right) F'_{bsc+}} \leq 1.0$$

#### 5.3.1.3.2.2 Maximum Negative Moment.

$$\frac{3 f_{an}}{5 F_a} + \frac{0.85 |f_{bsc-}|}{\left(1 - \frac{12 f_{an}}{23 F'_e}\right) F_{ys}} \leq 1.0$$

5.3.1.3.2.3 Stiffener End Checks. The stiffener section is checked using AISC Formula (1.6-1b).

At Joint i:

If  $M_{ij}$  is positive (clockwise):

$$\frac{f_{an}}{F_{ys}} + \frac{M_{ij} y'}{I_e F'_{bsc+}} \leq 1.0$$

where

$F'_{bsc+}$  is as defined in Section 5.3.1.3.1.1.

If  $M_{ij}$  is negative (counterclockwise):

$$\frac{f_{an}}{F_{ys}} - \frac{M_{ij} (d - y')}{I_e F_{ys}} \leq 1.0$$

At Joint j:

If  $M_{ji}$  is positive (clockwise):

$$\frac{f_{an}}{F_{ys}} + \frac{M_{ji} (d - y')}{I_e F_{ys}} \leq 1.0$$

If  $M_{ji}$  is negative (counterclockwise):

$$\frac{f_{an}}{F_{ys}} - \frac{M_{ji} y'}{I_e F'_{bsc+}} \leq 1.0$$

where

$M_{ij}$ ,  $M_{ji}$  = stiffener end moments at Joints i and j, respectively, due to excursion vacuum or pressure conditions, where end moments are calculated using the procedure given in Section 5.1.1.1. (Joint j is the joint adjacent to and clockwise from Joint i.) (k-in.)

5.3.2 Simultaneous Axial Tension and Transverse Loading. The trial stiffener section must satisfy the provisions of Sections 5.3.2.1, 5.3.2.2 and 5.3.2.3 following for all loading cases in which the stiffener is subjected to simultaneous axial tension and transverse loading.

5.3.2.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.

$$\frac{f_{an}}{0.60 F_{ys}} + \frac{f_{bst+}}{F_{bst+}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$\frac{f_{an}}{0.60 F_{ys}} + \frac{|f_{bst-}|}{F_{bst-}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$f_{bsc+} \leq F_{bsc+}$$

$$|f_{bsc-}| \leq F_{bsc-}$$

where

$f_{an}$  = maximum axial tensile stress in stiffener and adjacent effective plate on side n, as determined in Section 5.2.1 (ksi)

$F_{ys}$  = stiffener yield stress (ksi)

$f_{bst+}$  = maximum stiffener tensile bending stress due to maximum positive moment, for normal operation excluding wind and seismic forces, from Section 5.1.2 (ksi)

$F_{bst+}$  = allowable stiffener tensile bending stress due to positive moment in the absence of axial force, from Section 5.1.3 (ksi)

$f_{bst-}$  = maximum stiffener tensile bending stress due to maximum negative moment, for normal operation excluding wind and seismic forces, from Section 5.1.2 (ksi)

$F_{bst-}$  = allowable stiffener tensile bending stress due to negative moment in the absence of axial force, from Section 5.1.3.

$f_{bsc+}$ ,  $F_{bsc+}$ ,  $f_{bsc-}$  and  $F_{bsc-}$  are as defined in Section 5.3.1

**5.3.2.2 Normal Operating Conditions, Including Wind or Seismic Effects.** Allowable stresses  $0.60F_{ys}$ ,  $F_{bst+}$ ,  $F_{bst-}$ ,  $F_{bsc+}$ , and  $F_{bsc-}$  are increased by 1/3 in accordance with AISC Section 1.5.6.

$$\frac{f_{an}}{0.80 F_{ys}} + \frac{3 f_{bst+}}{4 F_{bst+}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$\frac{f_{an}}{0.80 F_{ys}} + \frac{3 |f_{bst-}|}{4 F_{bst-}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$f_{bsc+} \leq \frac{4}{3} F_{bsc+}$$

$$|f_{bsc-}| \leq \frac{4}{3} F_{bsc-}$$

where

$f_{bst+}$ ,  $f_{bst-}$ ,  $f_{bsc+}$ , and  $f_{bsc-}$  are determined as shown in Section 5.1.2, under normal operation including wind or seismic forces.

5.3.2.3 Excursion Vacuum or Pressure Conditions. For this loading case, the allowable stresses  $0.60 F_{ys}$ ,  $F_{bst+}$ ,  $F_{bst-}$ ,  $F_{bsc+}$  and  $F_{bsc-}$  are increased by 2/3 or set equal to the yield stress, whichever is less.

$$\frac{f_{an}}{F_{ys}} + \frac{f_{bst+}}{F_{ys}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$\frac{f_{an}}{F_{ys}} + \frac{|f_{bst-}|}{F_{ys}} \leq 1.0 \quad (\text{AISC Formula (1.6-1b)})$$

$$|f_{bsc-}| \leq F_{ys}$$

$$f_{bsc+} \leq F'_{bsc+}$$

where

$$F'_{bsc+} = \frac{5}{3} F_{bsc+} \leq F_{ys}$$

$f_{bst+}$ ,  $f_{bst-}$ ,  $f_{bsc+}$ , and  $f_{bsc-}$  are determined as shown in Section 5.1.2, under excursion conditions.

5.4 Maximum Plate Stress. If the plate yield stress,  $F_{yp}$ , is less than the stiffener yield stress,  $F_{ys}$ , the maximum combined compressive axial and bending stresses in the effective portion of the plate adjacent to the stiffener are checked. If any of the requirements of Section 5.4.1 or 5.4.2 are not satisfied, a stiffener section with a larger section modulus is selected.

5.4.1 Simultaneous Axial Compression and Transverse Loading. The provisions of Sections 5.4.1.1, 5.4.1.2, and 5.4.1.3 must be satisfied for all loading cases in which the effective portion of the plate adjacent to the stiffener is subjected to stresses caused by simultaneous axial compression and transfer loading.

5.4.1.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.

$$\frac{f_{an}}{0.60 F_{yp}} + \frac{|f_{bp-}|}{F_{bp-}} \leq 1.0$$

$$f_{bp+} \leq F_{bp+}$$

where

$f_{an}$  = maximum axial compressive stress in effective plate on side n, as determined in Section 5.2.1 (ksi)

$F_{yp}$  = plate yield stress (ksi)

$f_{bp-}$  = maximum effective plate compressive bending stress due to negative moment, for normal operation excluding wind and seismic forces, as determined in Section 5.1.2 (ksi)

$F_{bp-}$  = allowable effective plate bending stress due to negative moment in the absence of axial force, from Section 5.1.3 (ksi)

$f_{bp+}$  = maximum effective plate tensile bending stress due to positive moment, for normal operation excluding wind and seismic forces, as determined in Section 5.1.2 (ksi)

$F_{bp+}$  = allowable effective plate bending stress due to positive moment in the absence of axial force, from Section 5.1.3 (ksi)

5.4.1.2 Normal Operating Conditions, Including Wind or Seismic Effects.

$$\frac{f_{an}}{0.80 F_{yp}} + \frac{3 |f_{bp-}|}{4 F_{bp-}} \leq 1.0$$

$$f_{bp+} \leq \frac{4}{3} F_{bp+}$$

In the above formulas,  $f_{bp-}$  and  $f_{bp+}$  are calculated as shown in Section 5.1.2, for normal operation including wind or seismic forces.

5.4.1.3 Excursion Conditions.

$$\frac{f_{an}}{F_{yp}} + \frac{f_{bp-}}{F_{yp}} \leq 1.0$$

$$f_{bp+} \leq F_{yp}$$

In the above formulas,  $f_{bp-}$  and  $f_{bp+}$  are calculated as shown in Section 5.1.2, for excursion conditions.

5.4.2 Simultaneous Axial Tension and Transverse Loading. The provisions of Sections 5.4.2.1, 5.4.2.2, and 5.4.2.3 must be satisfied for all loading cases in which the effective portion of the plate adjacent to the stiffener is subjected to stresses caused by simultaneous axial tension and transverse loading.

5.4.2.1 Normal Operating Conditions, Excluding Wind and Seismic Effects.

$$\frac{|f_{an}|}{0.60 F_{yp}} + \frac{f_{bp+}}{F_{bp+}} \leq 1.0$$

$$|f_{bp-}| \leq F_{bp-}$$

where

$f_{an}$  = maximum axial tensile stress in effective plate on side n, as determined in Section 5.2.1.

$f_{bp+}$  = maximum effective plate tensile bending stress due to positive moment, for normal operation excluding wind and seismic forces, as determined in Section 5.1.2 (ksi)

$f_{bp-}$  = maximum effective plate compressive bending stress due to negative moment, for normal operation excluding wind and seismic forces, as determined in Section 5.1.2 (ksi)

5.4.2.2 Normal Operating Conditions, Including Wind or Seismic Effects.

$$\frac{|f_{an}|}{0.80 F_{yp}} + \frac{3 f_{bp+}}{4 F_{bp+}} \leq 1.0$$

$$|f_{bp-}| \leq \frac{4}{3} F_{bp-}$$



In the above formulas,  $f_{bp+}$  and  $f_{bp-}$  are calculated as shown in Section 5.1.2, for normal operation including wind or seismic forces.

#### 5.4.2.3 Excursion Conditions.

$$\frac{|f_{an}|}{F_{yp}} + \frac{f_{bp+}}{F_{yp}} \leq 1.0$$

$$|f_{bp-}| \leq F_{yp}$$

In the above formulas,  $f_{bp+}$  and  $f_{bp-}$  are calculated as shown in Section 5.1.2, for excursion conditions.

5.5 Maximum Deflection. Each stiffener is selected such that the maximum deflection of the combined stiffener and adjacent effective plate is limited to the following.

$$\delta_{s,max} \leq \delta_{s,allow}$$

where

$\delta_{s,max}$  = maximum stiffener deflection, as calculated in Sections 5.5.1 and 5.5.2 (in.)

$\delta_{s,allow}$  = allowable stiffener deflection (in.)

$$= L_n (12 \text{ in./ft}) / D_{s,allow}$$

$L_n$  = stiffener length on side n (ft)

$D_{s,allow}$  = ratio of stiffener length to allowable stiffener deflection, as appropriate for the loading case.

#### 5.5.1 Simultaneous Axial Compression and Transverse Loading.

The effect of the axial compressive force on the maximum stiffener deflection must be considered when the stiffener is subjected to simultaneous axial compression and transverse loads. The stiffener deflections may be solved for by evaluating separately and then combining the two loading cases shown in Figure 8. This approach is presented by Roark and Young.<sup>38</sup>

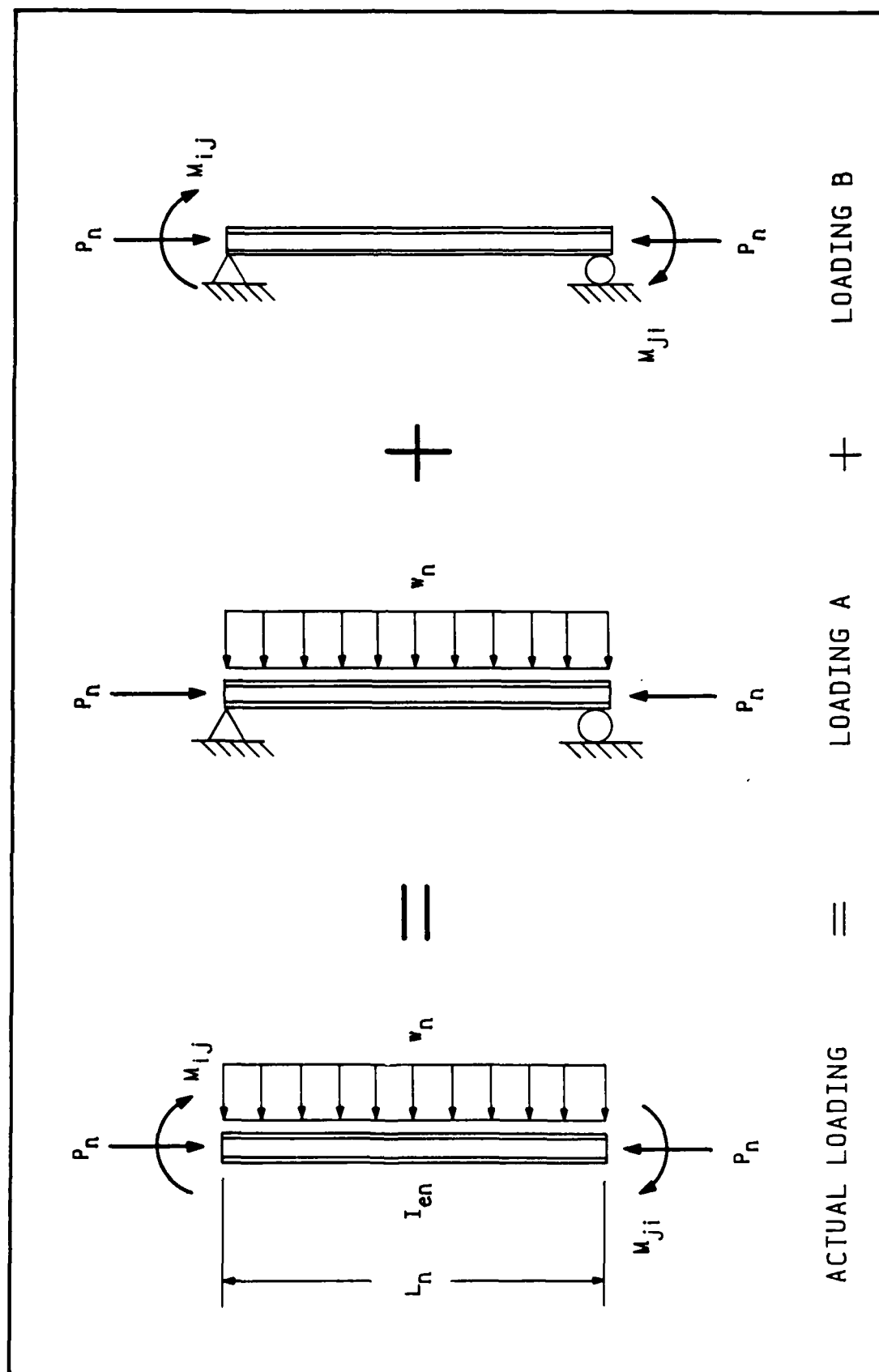


FIGURE 8. MODIFIED SUPERPOSITION OF STIFFENER LOADING

Loading A in Figure 7 matches Table 10, Case 2e, in Formulas for Stress and Strain:<sup>39</sup>

$$\delta_{sxA} = \frac{w_n}{12k_n^2 P_n} [\tan(6kL_n) \sin(12kx) + 72k_n^2 x^2 + \cos(12kx) - 1] - \frac{6w_n L_n x}{P_n}$$

Loading B in Figure 7 matches Table 10, Case 3e:<sup>40</sup>

$$\delta_{sxB} = -\frac{10^3 M_{ij}}{P_n} \left[ \frac{\sin(12kx)}{\tan(12kL_n)} - \cos(12kx) - \frac{x}{L_n} + 1 \right] - \frac{10^3 M_{ji}}{P_n} \left[ \frac{\sin(12kx)}{\sin(12kL_n)} - \frac{x}{L_n} \right]$$

Combining the two loading cases:

$$\delta_{sx} = \delta_{sxA} + \delta_{sxB}$$

where

$\delta_{sx}$  = stiffener deflection at distance  $x$  clockwise from Joint  $i$  (in.)

$x$  = distance clockwise from Joint  $i$  (ft.)

$w_n$  = uniformly distributed transverse load on stiffener  $n$ , from Section 2.7, as appropriate for the load case (plf)

$P_n$  = axial compressive force in stiffener  $n$ , as calculated in Section 2.7 (1b)

$$k = \left[ \frac{P_n}{10^3 E_s I_e} \right]^{1/2}$$

$E_s$  = stiffener modulus of elasticity (ksi)

$I_e$  = moment of inertia of combined stiffener and adjacent effective plate from Section 4.1 (in.<sup>4</sup>)

$M_{ij}$ ,  $M_{ji}$  = stiffener end moments at Joints  $i$  and  $j$ , respectively, where Joint  $j$  is the joint adjacent to and clockwise from Joint  $i$ , calculated as discussed below (k-in.)

$M_{ij}$  and  $M_{ji}$  are calculated using the method given in Section 5.1.1.1, except that  $M_{0n}$ , the fixed end moment for stiffener  $n$ , is calculated using the following equation:<sup>41</sup>

$$M_{0n} = \frac{w_n}{12,000 k^2} \left[ 1 - \frac{6kL_n}{\tan(6kL_n)} \right]$$

$\delta_{sx}$  is evaluated at specified intervals along the stiffener and the maximum deflection,  $\delta_{s,max}$ , is determined.

5.5.2 Simultaneous Axial Tension and Transverse Loading. The effect of axial tension, which tends to reduce the stiffener deflection, is ignored, and only the deflection due to transverse loads is calculated for stiffeners subjected to simultaneous axial tension and transverse loads. The stiffener deflection is calculated using a form of the equations given by Hughes and Gaylord.<sup>42</sup>

$$\begin{aligned} \delta_{sx} = & \frac{0.072 w_n x}{E_s I_e} (L_n^3 - 2L_n x^2 + x^3) + \frac{24 M_{ij} x}{L_n E_s I_e} (L_n - x) (2L_n - x) \\ & - \frac{24 M_{ji} L_n x}{E_s I_e} \left( 1 - \frac{x^2}{L_n^2} \right) \end{aligned}$$

where nomenclature is as given in Section 5.5.1, except that  $M_{ij}$  and  $M_{ji}$  are calculated as shown in Section 5.1.1.1, including calculation of the fixed-end moments as shown in Section 5.1.1.1.

$\delta_{sx}$  is evaluated at specified intervals along the stiffener and the maximum deflection,  $\delta_{s,max}$ , is determined.

5.6 Plate Girder Stiffener Checks. The AISC 1.10.5.4 stiffener moment of inertia and gross area requirements, as given in Section 4.7, are checked.

## 6. DUCT SECTION CHECKS

6.1 Effective Compression Flange Width and Stress. The reduced effective compression flange width and the associated flange compressive stress are calculated using the six step procedure below. Nomenclature is as shown in Figure 9.

1. A value for  $f$  is assumed, where  $f$  = computed compressive stress in the duct compression flange based on a reduced effective compression flange width (ksi).
2.  $b_e$ , the reduced effective compression flange width, in inches, is calculated.

$$b_e = \frac{253t_c}{\sqrt{f}} \left[ 1 - \frac{50.3}{(b/t_c) \sqrt{f}} \right] \leq b \quad (\text{AISC Equation (C3-1)})$$

where

$t_c$  = plate thickness of duct panel which is in compression (in.)

$b$  = actual width of stiffened compression element; clear distance between compression corner angles (in.)

$f$  = computed compressive stress in the duct compression flange based on the reduced effective compression flange width (ksi)

3. The duct section effective neutral axis location,  $y''$ , is calculated as follows.

$$\text{Let } A = (H + t_1 + t_3) t_4$$

$$B = (H + t_1 + t_3) t_2$$

$$C = (L_{X1} + b_e + L_{X2}) t_1$$

$$D = (t_4 + W + t_2) t_3$$

$$E = A_{L1}(t_1 + y_{L1})$$

$$F = A_{L2}(t_1 + y_{L2})$$

$$G = (t_1 + H + t_3) \frac{A}{2}$$

$$M = (t_1 + H + t_3) \frac{B}{2}$$

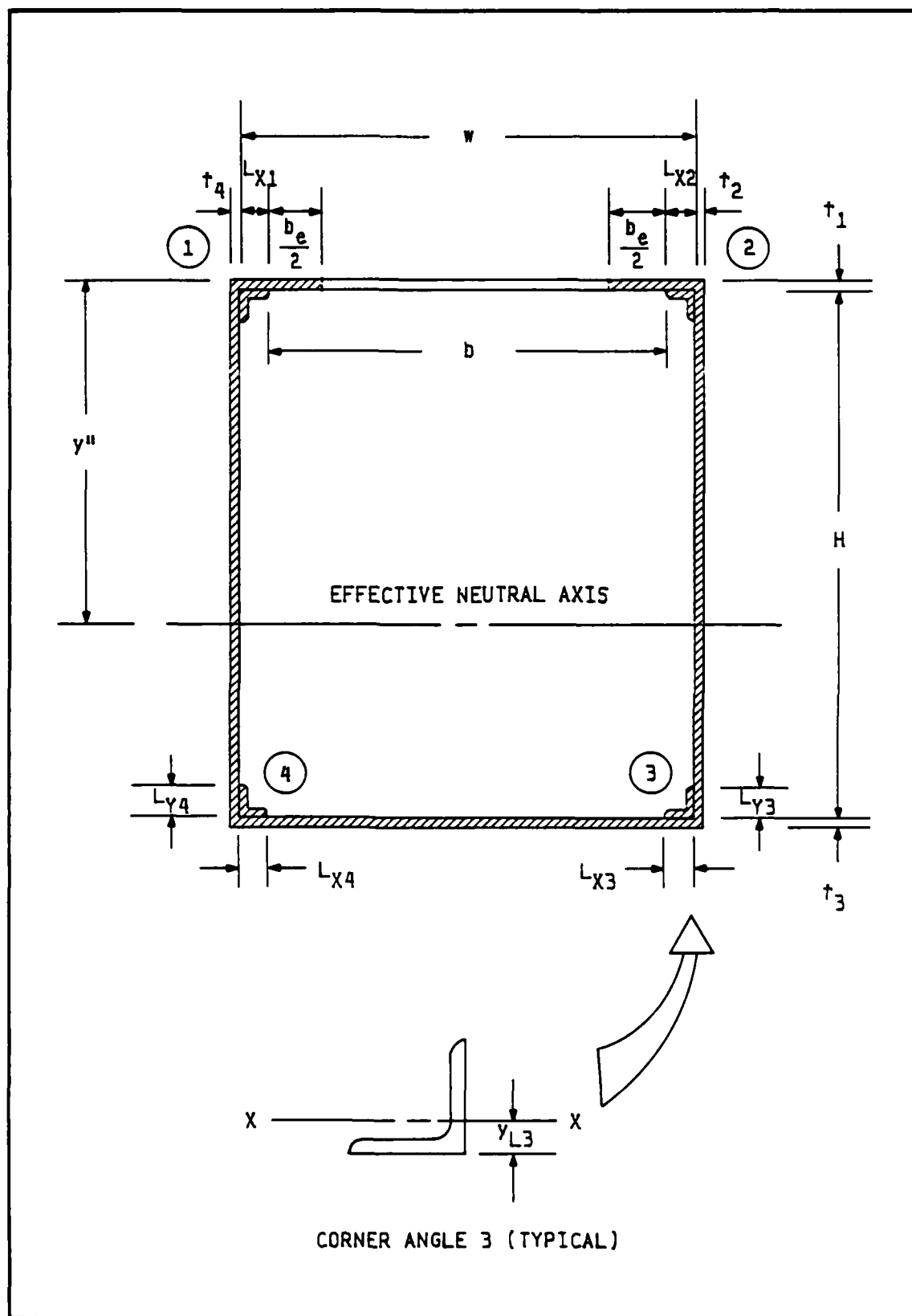


FIGURE 9. EFFECTIVE DUCT CROSS SECTION

$$N = (t_1 + H + \frac{t_3}{2})D$$

$$Q = A_{L4}(t_1 + H - y_{L4}) + A_{L3}(t_1 + H - y_{L3})$$

$$\text{then } y'' = \frac{E + F + G + M + N + Q}{A + B + C + D + A_{L1} + A_{L2} + A_{L3} + A_{L4}}$$

where

$L_{Xm}$  = length of horizontal leg of corner angle  $m$  (in.)

$y_{Lm}$  = vertical distance from exterior face of horizontal leg to centroid of corner angle  $m$  (in.)

$A_{Lm}$  = cross-sectional area of corner angle  $m$  (in.<sup>2</sup>)

$H$  = vertical dimension of rectangular duct cross section; from inside surface to inside surface of top and bottom duct plates (in.)

$W$  = horizontal dimension of rectangular duct cross section; from inside surface to inside surface of side duct plates (in.)

4. The effective moment of inertia of the duct section,  $I_{be}$ , based on the reduced effective compression flange width, is calculated.

$$\begin{aligned} I_{be} = & \frac{1}{12} (t_2 + t_4) (t_1 + H + t_3)^3 \\ & + (A + B) \left[ y'' - \frac{1}{2} (t_1 + H + t_3) \right]^2 \\ & + C (y'' - \frac{t_1}{2})^2 + D (t_1 + H + \frac{t_3}{2} - y'')^2 \\ & + I_{L1} + I_{L2} + I_{L3} + I_{L4} \\ & + A_{L1} (y'' - t_1 - y_{L1})^2 + A_{L2} (y'' - t_1 - y_{L2})^2 \\ & + A_{L3} (t_1 + H - y_{L3} - y'')^2 + A_{L4} (t_1 + H - y_{L4} - y'')^2 \end{aligned}$$

where

$I_{Lm}$  = moment of inertia about horizontal axis of corner angle  $m$  (in.<sup>4</sup>)

5. The compressive stress in the duct compression flange,  $f$ , based on the reduced effective compression flange width is calculated.

$$f = \frac{M_{CL} y''}{I_{be}} = \frac{0.0015 w_g L^2 y''}{I_{be}}$$

where

$M_{CL}$  = moment at center span of duct due to gravity loads

$w_g$  = uniformly distributed load on duct section due to gravity loads, from Section 2.6.2.2 (plf)

$L$  = duct clear span (ft.)

$y''$  = distance from effective neutral axis to extreme compression fiber, from Step 3 (in.)

$I_{be}$  = effective moment of inertia (in.<sup>4</sup>)

6. The value of  $f$  computed in Step 5 is compared with the value of  $f$  assumed in Step 1. If they differ by more than 0.005 ksi, a revised value of  $f$  is selected and Steps 1 through 6 are repeated.

6.2 Reduced Allowable Flange Stress. The reduced allowable flange stress is calculated from AISC Section 1.10.6.

$$F'_b = 0.60F_{yp} \left[ 1.0 - 0.0005 \frac{H(t_2 + t_4)}{W t_1} \left( \frac{H - L_{yt} - L_{yb}}{t} - \frac{760}{\sqrt{0.60F_{yp}}} \right) \right]$$

(From AISC Formula (1.10-5))

where

$F_{yp}$  = duct plate yield stress (ksi)

$H$  = vertical dimension of rectangular duct cross section; from inside surface to inside surface of top and bottom duct plates (in.)

$t_n$  = duct plate thickness of side  $n$  (in.)

$t$  = lesser of  $t_2$  or  $t_4$  (side duct plate thicknesses) (in.)

$W$  = horizontal dimension of rectangular duct cross section; from inside surface to inside surface of duct side plates (in.)

$L_{Yt}, L_{Yb}$  = length of top and bottom corner angle legs parallel to the vertical axis, respectively (in.)

$F'_b$  = reduced allowable bending stress in the duct compression flange (ksi)



If  $f > F'_b$ , the duct side plate thicknesses are increased, the size of the corner angles are increased, or the duct dimensions are modified to provide a greater effective section modulus.

6.3 Compression Flange Vertical Buckling. From AISC 1.10.2, if  $\frac{H - L_{Yt} - L_{Yb}}{t} > \frac{2,000}{\sqrt{F_{yp}}}$ , where  $t =$  lesser of  $t_2$  or  $t_4$ , the effective compression flange is checked for vertical buckling into the duct web. The equation used to check for compression flange vertical buckling is based on the discussion by Salmon and Johnson.<sup>43</sup> The following requirement must be satisfied:

$$f \leq \frac{\pi^2 E_p t^3}{24 (1 - \nu^2) (H - L_{Yt} - L_{Yb}) A_{cf} (16.5 + F_{yp})}$$

where

$f$  = computed compressive stress in the duct compression flange based on the reduced effective compression flange width, from Section 6.1 (ksi)

$E_p$  = plate modulus of elasticity (ksi)

$t$  = lesser of  $t_2$  or  $t_4$  (side duct plate thicknesses) (in.)

$\nu$  = Poisson's ratio for the duct plate

$H$  = vertical dimension of rectangular duct cross section; from inside surface to inside surface of top and bottom duct plates (in.)

$L_{Yt}$ ,  $L_{Yb}$  = length of top and bottom corner angle legs parallel to the vertical axis, respectively (in.)

$A_{cf}$  = effective compression flange cross-sectional area (in.<sup>2</sup>)

$$= 30 t^2 + (L_{Xt} + \frac{b_e}{2}) t_1 + A_{Lm}$$

$L_{Xt}$  = length of top corner angle leg parallel to the horizontal axis (in.)

$b_e$  = reduced effective compression flange width, from Section 6.1 (in.)

$t_1$  = duct top plate thickness (in.)

$A_{Lm}$  = corner angle  $m$  cross-sectional area, where  $m = 1$  or  $2$ , corresponding to the thinner duct side plate (in.)

$F_{yp}$  = plate yield stress (ksi)

If the above requirement is not satisfied, thicker duct side plates and/or larger corner angles are specified.

6.4 Web Shear. If the average web shear stress,  $f_v$ , as computed in Section 6.4.2, is more than the allowable web shear stress,  $F_v$ , as computed in Section 6.4.1, the side stiffener spacing is decreased or the side duct plate thickness is increased.

6.4.1 Allowable Web Shear Stress. From AISC Section 1.10.5.2,

$$F_v = \frac{F_{yp}}{2.89} (C_v) \leq 0.40 F_{yp} \quad (\text{AISC Equation (1.10-1)})$$

where

$$C_v = \frac{45,000 k}{F_{yp} \left( \frac{H - L_{Yt} - L_{Yb}}{t} \right)^2} \quad \text{when } C_v < 0.8$$

$$= \left( \frac{190}{\left( \frac{H - L_{Yt} - L_{Yb}}{t} \right)} \right) \sqrt{\frac{k}{F_{yp}}} \quad \text{when } C_v > 0.8$$

$$k = 4.00 + \frac{5.34}{\left( \frac{s}{H - L_{Yt} - L_{Yb}} \right)^2} \quad (s/H \text{ is always } < 1.0)$$

$H$  = vertical dimension of rectangular duct cross section; from inside surface to inside surface of top and bottom duct plates (in.)

$L_{Yt}$ ,  $L_{Yb}$  = length of top and bottom corner angle legs parallel to the vertical axis, respectively (in.)

$t$  = lesser of  $t_2$  or  $t_4$  (side duct plate thicknesses) (in.)

$F_{yp}$  = plate yield stress (ksi)

$s$  = stiffener spacing (in.)

The value of  $F_v$  calculated from AISC Equation (1.10-1) is more conservative than that calculated from AISC Equation (1.10-2), but is used here because the provisions of AISC Section 1.10.5.3 regarding

the required  $a/h$  ratio may not always be satisfied, as required for use of Equation (1.10-2).

#### 6.4.2 Average Web Shear Stress.

##### 6.4.2.1 End Panels.

$$f_v = \frac{w_g L}{2,000 H (t_2 + t_4)}$$

where

$f_v$  = average web shear stress (ksi)

$w_g$  = uniformly distributed load on duct section due to gravity loads from Section 2.6.2.2 (plf)

$L$  = duct span (ft.)

$H$  and  $t_n$  are defined in Section 6.1

##### 6.4.2.2 Interior Panels.

$$f_v = \frac{w_g (L - \frac{H}{12})}{2,000 H (t_2 + t_4)}$$

6.5 Combined Shear and Tension Stress. Combined shear and tension stress is checked in accordance with AISC Section 1.10.7.

$$f_b \leq (0.825 - 0.375 \frac{f_v}{F_v}) F_{yp} \quad (\text{AISC Equation (1.10-7)})$$

where

$f_b$  = maximum bending tensile stress in the web (ksi)

$$= \frac{0.0015 w_g L^2 (H + t_1 + t_3 - y'')}{I_{be}}$$

$y''$  = distance from extreme exterior compression fiber to the effective neutral axis of the duct section, as calculated in Section 6.1 (in.)

$I_{be}$  = moment of inertia of duct section based on the reduced effective compression flange width, as calculated in Section 6.1 (in.<sup>4</sup>)

$f_v$  = average web shear stress, as calculated in Section 6.4.2 (ksi)

$F_v$  = allowable web shear stress, as calculated in Section 6.4.1 (ksi)

If this provision is not satisfied, the duct side panel plate thicknesses are increased.

#### 7. BEARING STIFFENER DESIGN

The rigid frame approach is used at the duct support points where bearing stiffeners are required. The rigid frame stiffener design approach presented in Section 5 is used with the following modifications.

The effective plate widths adjacent to the bearing (side) stiffeners,  $b_{en}$ , are equal to 12 times the adjacent plate thicknesses, in accordance with AISC 1.10.5.1. This changes  $I_e$ , as calculated in Section 4.1.

The axial force in the bearing stiffener due to tension field action is

$$P_s = \frac{1}{4} (w_g L + w_b) ,$$

as compared to the equation for  $P_s$  given in Section 2.6.2.2.

## APPENDIX C

### COMPUTER PROGRAMS

The following computer programs implement the detailed ductwork design procedures presented in Appendix B. Representative output is given in Appendix D. These diskette-based computer programs are written for the Digital Equipment Corporation Professional 350 personal computer. The PRO/BASIC programming language, a version of the BASIC programming language published by the Digital Equipment Corporation, is used.

Due to memory limitations of the personal computer, the ductwork design procedure is separated into eight main programs. However, the ductwork designer need only load and run the first program. Subsequent programs are automatically chained to (loaded and run) with no prompting from the designer. The program user is, however, kept informed of which program is currently running via prompts to the computer screen. All the programs are interactive, and provide detailed instructions to the designer as the programs proceed. Thus, no prior experience with the programs is required before a complete ductwork structural design may be accomplished. The only prerequisite is a basic knowledge of how to turn on the computer, enter the PRO/BASIC mode, and load and run the first program.

The designer uses the first program, DUCT1, to enter most of the ductwork structural design parameters, such as physical dimensions of the duct, basic design loads, and material properties. Program DUCT2 calculates required duct plate thicknesses and transverse stiffener spacings for both interior and end duct panels. The designer inputs further design parameters for the transverse stiffeners using program DUCT3. Program DUCT4 is used to select transverse pinned-end stiffeners. Transverse loads and load combinations for use in the design of transverse rigid frame stiffeners are computed in program DUCT5. These load combinations are then used to design transverse rigid frame stiffeners in program DUCT6. Program DUCT6A is a two line program which enables DUCT5 to chain to DUCT6. Program DUCT7 performs duct section checks, where the duct section is considered to be a

simply supported bending member. Program DUCT8A is another two line program which enables DUCT5 to chain to DUCT8. The designer uses program DUCT8 to select the bearing stiffeners.

Programs DUCT4, DUCT6, DUCT7, and DUCT8 require the use of data from several different diskette-based files. These include file WSHAPE, which contains cross-sectional dimensions and properties of wide-flange beams, and file WT, which contains cross-sectional dimensions and properties of structural tees. Also included are files C and EA, which contain cross-sectional dimensions and properties of channels and equal-leg angles, respectively. Since the data contained in these four files are readily available in the AISC Manual of Steel Construction, they are not reproduced herein.

DUCT1.BAS

15:50

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SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT1
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO ESTABLISH THE DESIGN PARAMETERS
40 REM   TO BE USED IN THE STRUCTURAL DESIGN OF A HORIZONTAL SECTION OF COAL-
50 REM   FUELED POWER PLANT DUCTWORK
60 REM
70 OPEN 'LP:' FOR OUTPUT AS FILE #1
80 LET I3=3\I4=4
90 DIM LFT(14),PLANGLE(13),SS(4),T(4)
100 PRINT \ PRINT
110 PRINT 'DO YOU WANT A HARD COPY OF THE PROGRAM OUTPUT? (Y OR N)'
120 INPUT HCOPI$
130 IF HCOPI$='Y' GOTO 150
140 PRINT CHR$(27)+'[?4i'\ GOTO 180
150   PRINT CHR$(27)+'[?4i'
160   PRINT #1,CHR$(12)
170   PRINT CHR$(27)+'[?5i'
180 PRINT \ PRINT \ PRINT TAB(26);'DUCTWORK STRUCTURAL DESIGN'\ PRINT \ PRINT
190 PRINT 'WHAT IS THE DUCT SPAN (CLEAR DISTANCE BETWEEN SUPPORTS) IN FEET?'
200 INPUT LSPAN\ PRINT
210 PRINT 'INPUT THE WIDTHS OF SIDES 1,2,3 AND 4 IN FEET.'
220 PRINT '(SIDE 1=TOP, SIDES 2 AND 4=SIDES, SIDE 3=BOTTOM)'
230 INPUT LFT(1),LFT(2),LFT(3),LFT(4)\ PRINT \ PRINT
240 PRINT 'THE FOLLOWING INPUT IS USED TO CALCULATE THE ADJUSTED ';
250 PRINT 'MAINTENANCE LIVE LOAD.\' \ PRINT
260 PRINT 'INPUT THE ANGLE BETWEEN THE TOP PLATE AND HORIZONTAL AND THE '
270 PRINT 'ANGLE BETWEEN THE BOTTOM PLATE AND HORIZONTAL, IN DEGREES.'
280 PRINT '(MUST BE LESS THAN OR EQUAL TO 45 DEGREES)'
290 INPUT PLANGLE(1),PLANGLE(3)\ PRINT
300 PRINT 'WHAT IS THE NOMINAL MAINTENANCE LIVE LOAD IN PSF?'
310 INPUT LR\ PRINT
320 PRINT 'INPUT AN INITIAL ESTIMATION OF THE STIFFENER SPACING IN INCHES'
330 PRINT '(USE INITIAL EST. OF 36 IN. IF NO BETTER VALUE IS AVAILABLE)'
340 INPUT SSS\ PRINT \ PRINT
350 SS(1)=SS\SS(2)=SS\SS(3)=SS\SS(4)=SS
360 PRINT 'THE FOLLOWING INPUT IS USED TO CALCULATE DESIGN WIND LOADS.\' \ PRINT
370 PRINT 'WHAT IS THE HEIGHT OF THE TOP OF THE DUCT ABOVE THE GROUND IN FT?'
380 INPUT H\ PRINT
390 PRINT 'WHAT IS MEAN HEIGHT OF THE DUCT SECTION ABOVE THE GROUND IN FT?'
400 PRINT '(HEIGHT OF CENTERLINE OF THE DUCT SECTION ABOVE THE GROUND)'
410 INPUT Z\ PRINT
420 PRINT 'WHAT IS THE BASIC WIND SPEED IN MILES PER HOUR?'
430 PRINT '(FROM PDM OR ANSI A58.1-1982, FIGURE 1, TABLE 7 OR SECTION 6.5)'
440 INPUT V\ PRINT
450 PRINT 'HOW MANY MILES INLAND FROM A HURRICANE OCEAN LINE?'
460 PRINT '(IF GREATER THAN 100 MILES ENTER 100)'
470 INPUT MILES\ PRINT
480 PRINT 'WHAT IS THE MINIMUM WIND LOADING, FROM PDM, IN PSF?'
490 PRINT '(DEFAULT VALUE IS 10 PSF, PER ANSI 58.1-1982, SECTION 6.4.2.1)'
500 INPUT QWMIN\ PRINT
510 PRINT 'WIND EXPOSURE CATEGORY C OR D?'
520 PRINT '(FROM ANSI 58.1-1982, SECTION 6.5.3, OR FROM PDM)'
530 INPUT EXPOSURE$\ PRINT
540 PRINT 'WILL THE DUCTWORK HAVE INSULATION AND LAGGING? (Y OR N)'
550 INPUT INSULLAG$\ PRINT

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DUCT1.BAS

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560 IF HCOPI$='N' GOTO 600
570 PRINT CHR$(27)+'[?4i'
580 PRINT #1,CHR$(12)
590 PRINT CHR$(27)+'[?5i'
600 PRINT 'IS THE BOTTOM DUCT PANEL EXPOSED TO WIND FORCES? (Y OR N)'
610 INPUT BOTWIND$ PRINT \ PRINT
620 PRINT 'THE FOLLOWING INPUT IS USED TO CALCULATE DESIGN SNOW LOADS.' \ PRINT
630 PRINT 'WHAT IS THE GROUND SNOW LOAD IN PSF?'
640 PRINT '(FROM PDM OR ANSI A58.1-1982, FIGURES 5,6, OR 7, TAB. 17, OR A7.2)'
650 INPUT PG \ PRINT
660 PRINT 'IS THE POWER PLANT IN ALASKA? (Y OR N)'
670 INPUT ALASKA$ \ PRINT
680 PRINT 'WHAT IS THE SNOW EXPOSURE FACTOR?'
690 PRINT '(FROM ANSI A58.1-1982, TAB. 18; =0.8, 0.9, 1.0, 1.1, OR 1.2)'
700 INPUT CE \ PRINT
710 PRINT 'IS THE DUCT FOR UNHEATED AIR OR FOR HEATED AIR/FLUE GAS? (U OR H)'
720 INPUT HEAT$ \ PRINT \ PRINT
730 PRINT 'THE FOLLOWING INPUT IS USED TO DETERMINE SEISMIC LOADING.' \ PRINT
740 PRINT 'WHAT IS THE SEISMIC ZONE?'
750 PRINT '(FROM PDM OR ANSI A58.1-1982, FIGURES 13 OR 14)'
760 INPUT SEISZ \ PRINT
770 PRINT 'INPUT AN INITIAL ESTIMATE OF PLATE THICKNESSES OF SIDES 1-4, IN.'
780 PRINT '(USE INITIAL ESTIMATE OF .3125 IN. IN ABSENCE OF A BETTER VALUE)'
790 INPUT T(1),T(2),T(3),T(4) \ PRINT
800 PRINT 'INPUT DUCT LINING DEAD LOAD, PSF'
810 INPUT QDL \ PRINT
820 PRINT 'WHAT IS THE UNIT WEIGHT OF THE DUCT PLATE IN PCF?'
830 INPUT UWP \ PRINT
840 PRINT 'WHAT IS THE ASH LIVE LOAD ON THE BOTTOM PANEL IN PSF?'
850 INPUT QLA \ PRINT
860 PRINT 'WHAT IS THE ASH LATERAL LIVE LOAD COEFFICIENT?'
870 PRINT '(USED TO DETERMINE ASH LIVE LOAD ON THE DUCT SIDE PANELS;'
880 PRINT 'SUGGESTED RANGE IS FROM .05 TO .10)'
890 INPUT CLA \ PRINT
900 IF HCOPI$='N' GOTO 940
910 PRINT CHR$(27)+'[?4i'
920 PRINT #1,CHR$(12)
930 PRINT CHR$(27)+'[?5i'
940 PRINT 'THE FOLLOWING INPUT IS USED TO DETERMINE OPERATING AND EXCURSION'
950 PRINT 'LOADS' \ PRINT
960 PRINT 'ENTER THE DESIGN OPERATING VACUUM FOR THIS DUCT SECTION (IN.W.G.)'
970 INPUT QLVIN \ PRINT
980 QLV=QLVIN*5.2
990 PRINT 'ENTER THE DESIGN OPERATING PRESSURE FOR THE DUCT SECTION (IN.W.G.)'
1000 INPUT QLPIN \ PRINT
1010 QLP=QLPIN*5.2
1020 PRINT 'ENTER THE DESIGN EXCURSION VACUUM FOR THIS DUCT SECTION (IN.W.G.)'
1030 INPUT QXVIN \ PRINT
1040 QXV=QXVIN*5.2
1050 PRINT 'ENTER THE DESIGN EXCURSION PRESSURE FOR THE DUCT SECTION (IN.W.G.)'
1060 INPUT QXPIN \ PRINT \ PRINT
1070 QXP=QXPIN*5.2
1080 PRINT 'THE FOLLOWING INPUT IS USED IN THE DUCT PLATE DESIGN' \ PRINT
1090 PRINT 'WHAT IS THE MODULUS OF ELASTICITY OF THE PLATE IN KSI?'
1100 INPUT EP \ PRINT
1110 E=EP*1000

```



DUCT1.BAS

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```
1120 PRINT "WHAT IS POISSON'S RATIO FOR THE PLATE?"
1130 INPUT PR\ PRINT
1140 PRINT 'ENTER THE MAXIMUM ALLOWABLE PLATE DEFLECTION FOR NORMAL OPERA';
1150 PRINT 'TING CONDITIONS:'
1160 PRINT 'ENTER XXX, WHERE MAX. ALLOW. DEFLECTION = PLATE SPAN/XXX'
1170 PRINT '(SUGGESTED VALUE FOR XXX IS 100)'
1180 INPUT ALDFL\ PRINT
1190 PRINT 'DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE PLATE DEFLECTION ';
1200 PRINT 'UNDER WIND OR\' \ PRINT 'SEISMIC FORCES? (Y OR N)'
1210 INPUT PROMPT$\ PRINT
1220 IF PROMPT$='N' GOTO 1270
1230 PRINT 'ENTER THE MAXIMUM ALLOWABLE PLATE DEFLECTION UNDER WIND OR SEIS';
1240 PRINT 'MIC FORCES:'
1250 PRINT 'ENTER XXX, WHERE MAX. ALLOW. DEFLECTION = PLATE SPAN/XXX'
1260 INPUT ALDWS\ PRINT
1270 PRINT 'DO YOU WANT TO SPECIFY A MAXIMUM PLATE DEFLECTION UNDER EXCURSI';
1280 PRINT 'ON\' \ PRINT 'PRESSURE OR VACUUM CONDITIONS? (Y OR N)'
1290 INPUT PROMPT1$\ PRINT
1300 IF PROMPT1$='N' GOTO 1350
1310 PRINT 'ENTER THE MAXIMUM ALLOWABLE PLATE DEFLECTION UNDER EXCURSION ';
1320 PRINT 'CONDITIONS:'
1330 PRINT 'ENTER XXX, WHERE MAX. ALLOW. DEFLECTION = PLATE SPAN/XXX'
1340 INPUT ALDX\ PRINT
1350 PRINT 'ENTER THE PLATE YIELD STRESS IN KSI'
1360 INPUT FYP\ PRINT \ PRINT
1370 OPEN 'DATA1' FOR OUTPUT AS FILE #2
1380 LET C$=', '
1390 PRINT #2, HCOPY$, C$, LSPAN$, C$, LR$, C$, H$, C$, Z$, C$, V$, C$, MILES$, C$, QMIN
1400 PRINT #2, EXPOSURE$, C$, INSULLAG$, C$, BOTWIND$, C$, PG$, C$, ALASKA$, C$, CE
1410 PRINT #2, HEAT$, C$, SEISZ$, C$, QDL$, C$, UWP$, C$, QLA$, C$, CLA$, C$, QLV$, C$, QLP$, C$, QXV
1420 PRINT #2, QXP$, C$, EP$, C$, E$, C$, PR$, C$, ALDFL$, C$, PROMPT$, C$, ALDWS$, C$, PROMPT1$
1430 PRINT #2, ALDX$, C$, FYP
1440 PRINT #2, LFT(1), C$, LFT(2), C$, LFT(3), C$, LFT(4), C$, PLANGLE(1), C$, PLANGLE(3)
1450 PRINT #2, SS(1), C$, SS(2), C$, SS(3), C$, SS(4), C$, T(1), C$, T(2), C$, T(3), C$, T(4)
1460 CLOSE #1, #2
1470 LET IO=0\ DIM LFT(IO), PLANGLE(IO), SS(IO), T(IO)
1480 PRINT CHR$(27)+'[?4i'
1490 PRINT 'CHAINING TO PROGRAM DUCT2; PLEASE WAIT\' \ PRINT \ PRINT
1500 CHAIN 'DUCT2'
```

DUCT2.BAS

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SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT2
20 REM
30 REM   THIS PROGRAM IS USED TO DETERMINE THE DUCT PLATE THICKNESS AND
40 REM   TRANSVERSE STIFFENER SPACING FOR BOTH INTERIOR DUCT PANELS AND THE
50 REM   END PANELS.
60 REM
70 PROGRAM DUCT2
80 LET I2=2\I3=3\I4=4\I6=6\I7=7
90 DIM ATPS(I3),ATD(I3),QX(I4),RNGFLG(I6),Q(I4),QD(I4),QWE(I4),QWE2(I7)
100 DIM STRANDDFL(I2,I6),RNGFLG1(I4,I3),STRDFL(I2,I4,I3),SDFLG$(I2,I4,I3)
110 DIM ENDSPACE1(I4),ENDSPACE2(I4),ENDSPACE(I4),QEP(I4),QW(I4),QLR(I4)
120 DIM LFT(I4),PLANGLE(I3),SS(I4),T(I4)
130 OPEN 'LP:' FOR OUTPUT AS FILE #1\ OPEN 'DATA1' FOR INPUT AS FILE #2
140 INPUT #2,HCOPY$,LSPAN,LR,H,Z,V,MILES,QWMIN
150 INPUT #2,EXPOSURE$,INSULLAG$,BOTWIND$,PG,ALASKA$,CE
160 INPUT #2,HEAT$.SEISZ,QDL,UWP,QLA,CLA,QLV,QLP,QXV
170 INPUT #2,QXP,EP,E,PR,ALDFL,PROMPT$,ALDWS,PROMPT1$
180 INPUT #2,ALDX,FYP
190 INPUT #2,LFT(1),LFT(2),LFT(3),LFT(4),PLANGLE(1),PLANGLE(3)
200 INPUT #2,SS(1),SS(2),SS(3),SS(4),T(1),T(2),T(3),T(4)\ CLOSE #2
210 IF HCOPY$='N' GOTO 230
220 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
230 DEF FN RAD( DEG )=DEG*(PI/180)\ RANGE$='####'
240 MAXALAS=FYP*.6\MAXALBS=FYP*.75
250 MAXAASWS=MAXALAS*4/3\MAXABSWS=MAXALBS*4/3
260 REM   INTERIOR PANEL PLATE THICKNESS AND STIFFENER SPACING DETERMINATION
270 REM   Execute Plate Loading Subroutines
280 GOSUB 3660\ GOSUB 3790\ GOSUB 4610\ GDSUB 4830\ GOSUB 4870\ GOSUB 5050
290 GOSUB 5260\ PRINT \ PRINT
300 PRINT 'YOU NOW HAVE TWO OPTIONS, AS DESCRIBED BELOW:\ PRINT
310 PRINT '1.  UNDER OPTION 1, THIS PROGRAM WILL GENERATE A SET OF TABLES DI';
320 PRINT 'SPLAYING'\ PRINT 'MAXIMUM PLATE STRESSES AND DEFLECTIONS FOR VARIO';
330 PRINT 'US STIFFENER SPACING AND PLATE'\ PRINT 'THICKNESS COMBINATIONS. F';
340 PRINT 'ROM THESE TABLES YOU WILL SELECT AN ACCEPTABLE PLATE'\ PRINT 'THIC';
350 PRINT 'KNES AND STIFFENER SPACING FOR EACH OF THE FOUR SIDES OF THE DUC';
360 PRINT 'T.  IT WILL'\ PRINT 'TAKE APPROXIMATELY 50 TO 60 MINUTES FOR THE C';
370 PRINT 'OMPUTER TO GENERATE THESE TABLES.\ PRINT \ PRINT '2.  UNDER OPTI';
380 PRINT 'ON 2, YOU MUST ENTER TRIAL VALUES OF PLATE THICKNESS AND STIFFENER';
390 PRINT 'SPACING FOR EACH OF THE FOUR DUCT SIDES.  MAXIMUM PLATE STRESSES';
400 PRINT 'AND DEFLECTIONS'\ PRINT 'ARE THEN CALCULATED AND DISPLAYED. YOU';
410 PRINT 'ARE GIVEN THE OPPORTUNITY TO CHANGE'\ PRINT 'PLATE THICKNESSES';
420 PRINT 'AND/OR STIFFENER SPACINGS AS REQUIRED.  OPTION 2 IS FASTER';
430 PRINT 'THAN OPTION 1, BUT THE MOST EFFICIENT DESIGN MAY BE OVERLOOKED';
440 PRINT 'USING OPTION 2.\ PRINT \ PRINT 'DO YOU WISH TO SELECT OPTION';
450 PRINT '1 OR OPTION 2? (ENTER 1 OR 2)'
460 INPUT OPTION\ PRINT \ PRINT \ PRINT \ IF OPTION=2 GOTO 1530
470 PRINT 'FOR EACH PLATE THICKNESS VS. STIFFENER SPACING COMBINATION IN EAC';
480 PRINT 'H OF THE'
490 PRINT 'FOLLOWING FOUR TABLES THE FOLLOWING INFORMATION IS TABULATED:'
500 PRINT \ PRINT '-----'
510 PRINT '| AA.AA | AA.AA = MAXIMUM DUCT PLATE STRESS UNDER NOR';
520 PRINT 'MAL OPERATING CONDITIONS'
530 PRINT '| B.BB | B.BB = MAXIMUM PLATE DEFLECTION UNDER NORMAL';
540 PRINT 'OPERATING CONDITIONS'
550 PRINT '| CC.CC | CC.CC = MAXIMUM PLATE STRESS UNDER WIND OR';

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DUCT2.BAS

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560 PRINT 'SEISMIC FORCES'
570 PRINT '| D.DD | D.DD = MAXIMUM PLATE DEFLECTION UNDER WIND OR';
580 PRINT ' SEISMIC FORCES'
590 PRINT '| EE.EE | EE.EE = MAXIMUM PLATE STRESS FOR PRESSURE EXCU';
600 PRINT 'RSION CONDITIONS'
610 PRINT '| F.FF | F.FF = MAXIMUM PLATE DEFLECTION FOR PRESSURE ';
620 PRINT 'EXCURSION CONDITIONS'
630 PRINT '-----'
640 PRINT 'ADDITIONAL NOTES: 1) STRESSES ARE IN KSI, DEFLECTIONS ARE';
650 PRINT ' IN INCHES.'
660 PRINT ' 2) AN ASTERISK (*) FOLLOWING A NUMBER ';
670 PRINT 'INDICATES THAT THE\ PRINT TAB(23);'STRESS INTERACTION ';
680 PRINT 'REQUIREMENT IS NOT SATISFIED FOR THIS\ PRINT TAB(23);
690 PRINT 'LOAD CONDITION, OR THE DEFLECTION EXCEEDS THE ALLOWABLE.'
700 PRINT TAB(19);'3) ***** INDICATES THAT THE LOAD/DIMENSIONS COMBIN';
710 PRINT 'ATION'
720 PRINT TAB(23);'IS OUTSIDE THE RANGE OF TIMOSHENKO'S METHOD, OR INVOLVES"
730 PRINT TAB(23);'CALCULATIONS WITH REAL NUMBERS OF MAGNITUDES EXCEEDING'
740 PRINT TAB(23);'THE REPRESENTATION CAPABILITY OF PRO BASIC ON THE DEC 350'
750 PRINT TAB(23);'COMPUTER.\ PRINT \ PRINT
760 FOR DSIDE=1 TO 4
770 IF HCOPY$='N' GOTO 790
780 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
790 PRINT TAB(8);'STRESSES AND DEFLECTIONS FOR SIDE';DSIDE;'DUCT PLATE';
800 PRINT ' (INTERIOR PANELS)'
810 PRINT \ PRINT \ PRINT TAB(18);
820 FOR J=1 TO 62\ PRINT '-';\ NEXT J\ PRINT
830 PRINT TAB(18);'|';TAB(37);'PLATE THICKNESS (INCHES)'
840 FOR J=1 TO 80\ PRINT '-';\ NEXT J\ PRINT
850 PRINT 'STIFFEN.I ALLOW. |';TAB(29);'|';TAB(39);'|';TAB(49);'|';
860 PRINT TAB(59);'|';TAB(69);'|'
870 PRINT 'SPACING | DEFLECT.| 3/16 | 1/4 | 5/16 | 3/8';
880 PRINT TAB(59);'| 7/16 | 1/2'
890 PRINT "(INCHES)| (INCHES)|";TAB(29);'|';TAB(39);'|';TAB(49);'|';
900 PRINT TAB(59);'|';TAB(69);'|'
910 FOR J=1 TO 80\ PRINT '-';\ NEXT J\ PRINT
920 IF SSP=66 GOTO 980
930 FOR SSP=24 TO 96 STEP 6
940 MAXADFL=SSP/ALDFL
950 IF PROMPT$='Y' THEN MAXADFLWS=SSP/ALDWS
960 IF PROMPT1$='Y' THEN MAXALDFLX=SSP/ALDX
970 IF SSP=66 GOTO 780
980 FOR II=1 TO 3
990 FOR JJ=1 TO 6\ RNGFLG(JJ)=0\ NEXT JJ\ PLTHK=.1875
1000 ON II GOTO 1020,1120,1250
1010 REM NORMAL OPERATING CONDITIONS (NO WIND OR SEISMIC FORCES)
1020 QQ=ABS(Q(DSIDE))/144\ LIMITA=MAXALAS
1030 LIMITB=MAXALBS\ LIMITD=MAXADFL
1040 REM Calculate Plate Stresses and Deflections
1050 GOSUB 5670\ PRINT TAB(8);'|';TAB(18);'|';
1060 REM Execute Plate Stress Print Subroutine
1070 GOSUB 5780\ PRINT TAB(8);'|';TAB(12);
1080 PRINT USING '#.##',MAXADFL;\ PRINT TAB(18);'|';
1090 REM Execute Plate Deflection Print Subroutine
1100 GOSUB 5870\ GOTO 1370
1110 REM NORMAL OPERATING CONDITIONS (INCLUDING WIND OR SEISMIC FORCES)

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1120      QQ=ABS(QWE(DSIDE))/144\LIMITA=MAXAASWS\LIMITB=MAXABSWS
1130      IF PROMPT$='N' THEN LIMITD=100 ELSE LIMITD=MAXADFLWS
1140 REM    Calculate Plate Stresses and Deflections
1150      GOSUB 5670\ PRINT TAB(3);SSP;TAB(8);'|';TAB(18);'|';
1160 REM    Execute Plate Stress Print Subroutine
1170      GOSUB 5780\ PRINT TAB(8);'|';TAB(12);
1180      IF PROMPT$='Y' GOTO 1210
1190      PRINT 'N/A';TAB(18);'|';
1200      GOTO 1230
1210      PRINT USING '#.##',MAXADFLWS;\ PRINT TAB(18);'|';
1220 REM    Execute Plate Deflection Print Subroutine
1230      GOSUB 5870\ GOTO 1370
1240 REM    EXCURSION VACUUM OR PRESSURE CONDITIONS
1250      QQ=ABS(QX(DSIDE))/144\LIMITA=FYP\LIMITB=FYP
1260      IF PROMPT1$='N' THEN LIMITD=100 ELSE LIMITD=MAXALDFLX
1270 REM    Calculate Plate Stresses and Deflections
1280      GOSUB 5670\ PRINT TAB(8);'|';TAB(18);'|';
1290 REM    Execute Plate Stress Print Subroutine
1300      GOSUB 5780\ PRINT TAB(8);'|';TAB(12);
1310      IF PROMPT1$='Y' GOTO 1340
1320      PRINT 'N/A';TAB(18);'|';
1330      GOTO 1360
1340      PRINT USING '#.##',MAXALDFLX;\ PRINT TAB(18);'|';
1350 REM    Execute Plate Deflection Print Subroutine
1360      GOSUB 5870
1370      NEXT II
1380      FOR I=1 TO 80\ PRINT '--';\ NEXT I\ PRINT
1390      NEXT SSP
1400 NEXT DSIDE\ PRINT \ PRINT
1410 IF HCOPY$='N' THEN GOTO 1430
1420 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
1430 PRINT 'FROM THE PRECEDING TABLES SELECT THE STIFFENER SPACING AND PLATE'
1440 PRINT 'THICKNESS FOR EACH SIDE OF THE DUCT. IF STIFFENERS WITH RIGID'
1450 PRINT '(MOMENT-RESISTING) CONNECTIONS AT THE DUCT CORNERS ARE TO BE USED,'
1460 PRINT 'THE STIFFENER SPACINGS SELECTED FOR EACH SIDE OF THE DUCT MUST BE'
1470 PRINT 'EQUAL. IF PINNED (NON MOMENT-RESISTING) CONNECTIONS AT THE DUCT'
1480 PRINT 'CORNERS ARE TO BE USED, THE STIFFENER SPACINGS FOR SEPARATE SIDES'
1490 PRINT 'OF THE DUCT MAY BE DIFFERENT. HOWEVER, ALL STIFFENER SPACINGS'
1500 PRINT 'CHOSEN SHOULD BE EVEN MULTIPLES OF THE MINIMUM STIFFENER SPACING'
1510 PRINT 'SELECTED. IN EITHER CASE, PLATE THICKNESSES MAY VARY FROM SIDE TO'
1520 PRINT 'SIDE.'\ PRINT \ PRINT
1530 FOR I=1 TO 4
1540 PRINT 'ENTER THE PLATE THICKNESS (INCHES) AND STIFFENER SPACING (INCH';
1550 PRINT 'ES) FOR SIDE';I
1560 INPUT T(I),SS(I)\ PRINT
1570 NEXT I
1580 PRINT 'SHALL A CORROSION ALLOWANCE BE ADDED TO THE PLATE THICKNESS ON ';
1590 PRINT 'EACH SIDE OF'\ PRINT 'THE DUCT? (Y OR N)'
1600 INPUT CORR$\ PRINT \ IF CORR$='N' GOTO 1680
1610 PRINT 'ENTER THE CORROSION ALLOWANCE IN DECIMALS OF AN INCH'
1620 INPUT CRA\ PRINT
1630 PRINT 'NOTE: THE ADDITIONAL PLATE THICKNESS DUE TO THE CORROSION ALLOW';
1640 PRINT 'ANCE IS NOT'\ PRINT TAB(7);'CONSIDERED IN ANY STRUCTURAL CALCULA';
1650 PRINT 'TIONS, EXCEPT THAT THE PLATE DEAD'\ PRINT TAB(7);'LOAD IS INCREA';
1660 PRINT 'SED AS APPROPRIATE.'\ PRINT
1670 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I

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1680 IF HCOPY$='N' GOTO 1700
1690 PRINT CHR$(27)+'[?4i'
1700 PRINT 'STRESSES AND DEFLECTIONS ARE BEING CALCULATED; PLEASE WAIT'
1710 IF HCOPY$='N' GOTO 1740
1720 PRINT CHR$(27)+'[?5i'
1730 REM Recalculate Plate Loads
1740 GOSUB 3660\ GOSUB 3790\ GOSUB 4870\ GOSUB 5050\ GOSUB 5260
1750 IF CORR$='N' GOTO 1780
1760 FOR I=1 TO 4\T(I)=T(I)-CRA\ NEXT I
1770 REM Calculate Stresses and Deflections Based on the Actual Dimensions
1780 FOR DSIDE=1 TO 4
1790 PLTHK=T(DSIDE)\SSP=SS(DSIDE)
1800 FOR II=1 TO 3
1810 ON II GOTO 1820,1930,2050
1820 QQ=ABS(Q(DSIDE))/144\ GOSUB 5450
1830 RNGFLG1(DSIDE,II)=RANGEFLAG
1840 STRDFL(1,DSIDE,II)=MAXSTR/1000
1850 STRDFL(2,DSIDE,II)=MAXDFL
1860 IF STRESS1/(.6*FYP)+STRESS2/(.75*FYP)>1 THEN 1880
1870 SDFLG$(1,DSIDE,II)=' \' GOTO 1890
1880 SDFLG$(1,DSIDE,II)='*'
1890 MAXADFL=SS(DSIDE)/ALDFL
1900 IF MAXDFL>MAXADFL THEN SDFLG$(2,DSIDE,II)='*\ GOTO 1920
1910 SDFLG$(2,DSIDE,II)=' '
1920 GOTO 2150
1930 QQ=ABS(QWE(DSIDE))/144\ GOSUB 5450
1940 RNGFLG1(DSIDE,II)=RANGEFLAG
1950 STRDFL(1,DSIDE,II)=MAXSTR/1000
1960 STRDFL(2,DSIDE,II)=MAXDFL
1970 IF STRESS1/(.8*FYP)+STRESS2/FYP>1 THEN 1990
1980 SDFLG$(1,DSIDE,II)=' \' GOTO 2000
1990 SDFLG$(1,DSIDE,II)='*'
2000 IF PROMPT$='N' THEN SDFLG$(2,DSIDE,II)=' \' GOTO 2040
2010 MAXADFL=SS(DSIDE)/ALDWS
2020 IF MAXDFL>MAXADFL THEN SDFLG$(2,DSIDE,II)='*\ GOTO 2040
2030 SDFLG$(2,DSIDE,II)=' '
2040 GOTO 2150
2050 QQ=ABS(QX(DSIDE))/144\ GOSUB 5450
2060 RNGFLG1(DSIDE,II)=RANGEFLAG
2070 STRDFL(1,DSIDE,II)=MAXSTR/1000
2080 STRDFL(2,DSIDE,II)=MAXDFL
2090 IF STRESS1+STRESS2>FYP THEN SDFLG$(1,DSIDE,II)='*\ GOTO 2110
2100 SDFLG$(1,DSIDE,II)=' '
2110 IF PROMPT1$='N' THEN SDFLG$(2,DSIDE,II)=' \' GOTO 2150
2120 MAXADFL=SS(DSIDE)/ALDX
2130 IF MAXDFL>MAXADFL THEN SDFLG$(2,DSIDE,II)='*\ GOTO 2150
2140 SDFLG$(2,DSIDE,II)=' '
2150 NEXT II
2160 NEXT DSIDE\ PRINT \ PRINT
2170 IF CORR$='N' GOTO 2190
2180 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
2190 IF HCOPY$='N' GOTO 2210
2200 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
2210 PRINT TAB(6);'STRESSES AND DEFLECTIONS BASED ON THE ACTUAL DIMENSIONS';
2220 PRINT 'SELECTED'\ PRINT TAB(20);'(INTERIOR PANELS - NONLINEAR THEORY)'
2230 PRINT \ PRINT \ PRINT TAB(31);

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2240 FOR I=1 TO 44\ PRINT '-';\ NEXT I\ PRINT \ PRINT TAB(31);
2250 FOR I=1 TO 4\ PRINT '| SIDE';I;'\ NEXT I\ PRINT
2260 FOR I=1 TO 31\ PRINT '-';\ NEXT I
2270 FOR I=1 TO 44\ PRINT '=';\ NEXT I\ PRINT
2280 PRINT 'PLATE THICKNESS (INCHES)';TAB(31);
2290 FOR I=1 TO 4\ PRINT USING '| .###' ,T(I);\ NEXT I\ PRINT
2300 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
2310 PRINT 'STIFFENER SPACING (INCHES)';TAB(31);
2320 FOR I=1 TO 4\ PRINT USING '| ##' ,SS(I);\ NEXT I\ PRINT
2330 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
2340 FOR JJ=1 TO 2
2350     IF JJ=2 GOTO 2380
2360     PRINT 'MAXIMUM STRESSES (KSI)';TAB(31);'|';TAB(42);'|';TAB(53);
2370     PRINT '|';TAB(64);'|'\ GOTO 2400
2380     PRINT 'MAXIMUM DEFLECTIONS (INCHES)';TAB(31);'|';TAB(42);'|';TAB(53);
2390     PRINT '|';TAB(64);'|'
2400     FOR II=1 TO 3
2410         ON II GOTO 2420,2430,2440
2420         PRINT '    NO WIND OR SEISMIC FORCES '\ GOTO 2450
2430         PRINT '    WIND OR SEISMIC FORCES '\ GOTO 2450
2440         PRINT '    EXCURSION CONDITIONS '\
2450         FOR DSIDE=1 TO 4
2460             IF RNGFLG1(DSIDE,II)=0 GOTO 2480
2470             PRINT USING '| 'LLLL ' ,RANGE$;\ GOTO 2490
2480             PRINT USING '| ###.##' ,STROFL(JJ,DSIDE,II);SDFLG$(JJ,DSIDE,II);
2490         NEXT DSIDE\ PRINT
2500     NEXT II
2510 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
2520 NEXT JJ\ PRINT \ PRINT
2530 PRINT 'NOTES: 1) AN ASTERISK (*) FOLLOWING A NUMBER INDICATES THAT THE';
2540 PRINT ' STRESS INTER-\ PRINT TAB(12);'ACTION REQUIREMENT IS NOT SATISF';
2550 PRINT 'IED FOR THIS LOAD CONDITION, OR THE\ PRINT TAB(12);'DEFLECTION ';
2560 PRINT 'EXCEEDS THE ALLOWABLE.'
2570 PRINT TAB(8);'2) ##### INDICATES THAT THE LOAD/DIMENSIONS COMBINATION I';
2580 PRINT 'S OUTSIDE THE\ PRINT TAB(12);"RANGE OF TIMOSHENKO'S METHOD OR IN";
2590 PRINT 'VOLVES CALCULATIONS WITH REAL\ PRINT TAB(12);'NUMBERS OF MAGNITU';
2600 PRINT 'DES EXCEEDING THE REPRESENTATION CAPABILITY OF\ PRINT TAB(12);
2610 PRINT 'PRO BASIC ON THE DEC 350 COMPUTER.'
2620 IF CORR$='N' GOTO 2700
2630 PRINT TAB(8);'3) THE PLATE THICKNESSES SHOWN IN THE ABOVE TABLE INCL';
2640 PRINT 'UDE THE CORROSION\ PRINT TAB(12);'ALLOWANCE. STRESSES AND DE';
2650 PRINT 'FLECTIONS SHOWN ABOVE ARE CALCULATED\ PRINT TAB(12);'IGNORING';
2660 PRINT ' THE ADDITIONAL PLATE THICKNESS DUE TO THE CORROSION'
2670 PRINT TAB(12);'ALLOWANCE, EXCEPT THAT THE ADDITIONAL WEIGHT OF THE ';
2680 PRINT 'PLATE IS\ PRINT TAB(12);'CONSIDERED.'
2690 FOR I=1 TO 4\T(I)=T(I)-CRA\ NEXT I
2700 PRINT \ PRINT \WARNING=0
2710 FOR JJ=1 TO 2\ FOR DSIDE=1 TO 4\ FOR II=1 TO 3
2720     IF SDFLG$(JJ,DSIDE,II)='*' THEN WARNING=1
2730 NEXT II\ NEXT DSIDE\ NEXT JJ\ IF WARNING=1 GOTO 2750
2740 PRINT \ PRINT \ GOTO 2790
2750 PRINT '*** WARNING *** THE STIFFENER SPACING/PLATE THICKNESS COMBINATI';
2760 PRINT 'ON SELECTED FOR\ PRINT TAB(17);'ONE OR MORE OF THE DUCT SIDES RE';
2770 PRINT 'SULTS IN STRESSES AND/OR\ PRINT TAB(17);'DEFLECTIONS THAT EXCEED';
2780 PRINT ' THE ALLOWABLE (SEE TABLE ABOVE).\ PRINT \ PRINT
2790 PRINT 'DO YOU WISH TO CHANGE A STIFFENER SPACING AND/OR PLATE THICKNESS';

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2800 PRINT ' PREVIOUSLY\ PRINT 'SELECTED? (Y OR N)'
2810 INPUT CHANGE$\ PRINT \ PRINT
2820 IF HCOPY$='N' GOTO 2840
2830 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
2840 IF CHANGE$='N' GOTO 2890
2850 PRINT \ PRINT 'PLEASE REENTER THE CORRECT PLATE THICKNESS/STIFFENER SPA';
2860 PRINT 'CING COMBINATIONS FOR\ PRINT 'ALL FOUR SIDES:\ PRINT
2870 GOTO 1530
2880 REM END PANEL TRANSVERSE STIFFENER SPACING DETERMINATION
2890 FOR I=1 TO 4\ENDSPACE1(I)=100\ENDSPACE2(I)=100\ NEXT I
2900 FOR I=1 TO 4
2910 FOR J=1 TO 3
2920 ON J GOTO 2930,2940,2950
2930 MAXLOAD=ABS(Q(I))\ALLOWSTRESS=.75*FYP\DFLRATIO=ALDFL\ GOTO 2960
2940 MAXLOAD=ABS(QWE(I))\ALLOWSTRESS=FYP\DFLRATIO=ALDWS\ GOTO 2960
2950 MAXLOAD=ABS(QX(I))\ALLOWSTRESS=FYP\DFLRATIO=ALDX\ GOTO 2960
2960 MAXENDSPACE1=SQR((192000*ALLOWSTRESS*T(I)^2)/MAXLOAD)
2970 IF MAXENDSPACE1<ENDSPACE1(I) THEN LET ENDSPACE1(I)=MAXENDSPACE1
2980 IF DFLRATIO=0 THEN LET DFLRATIO=1
2990 MAXENDSPACE2=((.22E+07*EP*T(I)^3)/(MAXLOAD*(1-PR^2)*DFLRATIO))^(1/3)
3000 IF MAXENDSPACE2<ENDSPACE2(I) THEN LET ENDSPACE2(I)=MAXENDSPACE2
3010 NEXT J
3020 IF ENDSPACE1(I)<ENDSPACE2(I) THEN ENDSPACE(I)=ENDSPACE1(I)\ GOTO 3040
3030 ENDSPACE(I)=ENDSPACE2(I)
3040 NEXT I
3050 IF CORR$='N' GOTO 3070
3060 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
3070 PRINT TAB(3);'MAXIMUM ALLOWABLE STIFFENER SPACINGS FOR DUCT END PANELS';
3080 PRINT ' (LINEAR THEORY)'
3090 PRINT \ PRINT \ PRINT TAB(31);
3100 FOR I=1 TO 4\ PRINT '-';\ NEXT I\ PRINT
3110 PRINT TAB(31);
3120 FOR I=1 TO 4\ PRINT 'I SIDE';I;\ NEXT I\ PRINT
3130 FOR I=1 TO 31\ PRINT '-';\ NEXT I
3140 FOR I=1 TO 44\ PRINT '=';\ NEXT I\ PRINT
3150 PRINT 'PLATE THICKNESS (INCHES)';TAB(31);
3160 FOR I=1 TO 4\ PRINT USING 'I .#### ',T(I);\ NEXT I\ PRINT
3170 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
3180 PRINT 'MAXIMUM STIFFENER SPACING';TAB(31);'|';TAB(42);'|';TAB(53);
3190 PRINT '|';TAB(64);'|'
3200 PRINT 'BASED ON PLATE STRESS';TAB(31);
3210 FOR I=1 TO 4\ PRINT USING 'I ## ',ENDSPACE1(I);\ NEXT I\ PRINT
3220 PRINT '(INCHES)';TAB(31);'|';TAB(42);'|';TAB(53);'|';TAB(64);'|'
3230 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
3240 PRINT 'MAXIMUM STIFFENER SPACING';TAB(31);'|';TAB(42);'|';TAB(53);
3250 PRINT '|';TAB(64);'|'
3260 PRINT 'BASED ON DEFLECTION';TAB(31);
3270 FOR I=1 TO 4\ PRINT USING 'I ## ',ENDSPACE2(I);\ NEXT I\ PRINT
3280 PRINT '(INCHES)';TAB(31);'|';TAB(42);'|';TAB(53);'|';TAB(64);'|'
3290 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT
3300 PRINT 'MAXIMUM ALLOWABLE END';TAB(31);'|';TAB(42);'|';TAB(53);
3310 PRINT '|';TAB(64);'|'
3320 PRINT 'PANEL STIFFENER SPACING';TAB(31);
3330 FOR I=1 TO 4\ PRINT USING 'I ## ',ENDSPACE(I);\ NEXT I\ PRINT
3340 PRINT '(INCHES)';TAB(31);'|';TAB(42);'|';TAB(53);'|';TAB(64);'|'
3350 FOR I=1 TO 75\ PRINT '-';\ NEXT I\ PRINT

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3360 PRINT 'NOTE: 1) THE MAXIMUM ALLOWABLE STIFFENER SPACINGS SHOWN ABOVE ' ;
3370 PRINT 'ARE BASED ON\' PRINT TAB(11); 'LINEAR THEORY. THE END PANELS ARE ' ;
3380 PRINT 'CONSIDERED TO BE SIMPLY SUPPORTED\' PRINT TAB(11); 'ALONG ONE ' ;
3390 PRINT 'STIFFENER AND FIXED ALONG THE OTHER. THE STIFFENERS ARE'
3400 PRINT TAB(11); 'ASSUMED TO PROVIDE NO RESTRAINT IN THE PLANE OF THE PLATE.'
3410 IF CORR$='N' GOTO 3450
3420 PRINT TAB(7); '2) THE PLATE THICKNESSES SHOWN ABOVE INCLUDE THE ' ;
3430 PRINT 'CORROSION ALLOWANCE\' PRINT TAB(11); 'PREVIOUSLY SPECIFIED.'
3440 FOR I=1 TO 4: T(I)=T(I)-CRA: NEXT I
3450 PRINT CHR$(27)+'[?4i'
3460 IF HCOPY$='N' GOTO 3480
3470 PRINT #1, CHR$(12)
3480 LET C$=', '
3490 OPEN 'DATA2' FOR OUTPUT AS FILE #2: OPEN 'DATA3' FOR OUTPUT AS FILE #3
3500 OPEN 'DATA5' FOR OUTPUT AS FILE #5
3510 PRINT #2, INSULLAG$; C$; LR; C$; LSPAN; C$; QLA; C$; PLANGLE(1); C$; PLANGLE(3)
3520 PRINT #2, LFT(1); C$; LFT(2); C$; LFT(3); C$; LFT(4)
3530 PRINT #3, CLA; C$; CORR$; C$; CRA; C$; LSPAN; C$; EP; C$; FYP; C$; SEISZ
3540 PRINT #3, UWP; C$; QDL; C$; QLA; C$; QLP; C$; QLV; C$; QS; C$; QXP; C$; QXV
3550 PRINT #3, LFT(1); C$; LFT(2); C$; LFT(3); C$; LFT(4); C$; QLR(1); C$; QLR(3)
3560 PRINT #3, T(1); C$; T(2); C$; T(3); C$; T(4); C$; QW(1); C$; QW(2); C$; QW(3); C$; QW(4)
3570 PRINT #5, SS(1); C$; SS(2); C$; SS(3); C$; SS(4)
3580 CLOSE #1, #2, #3, #5: LET IO=0
3590 DIM ATPS(10), ATD(10), QX(10)
3600 DIM Q(10), QD(10), QWE(10), QWE2(10), STRANDDFL(10,10), RNGFLG(10)
3610 DIM RNGFLG1(10,10), STRDFL(10,10,10), SDFLG$(10,10,10)
3620 DIM LFT(10), PLANGLE(10), SS(10), T(10), QEP(10), QW(10), QLR(10)
3630 DIM ENDSPEACE1(10), ENDSPEACE2(10), ENDSPEACE(10)
3640 PRINT 'CHAINING TO PROGRAM DUCT3; PLEASE WAIT\' CHAIN 'DUCT3'
3650 REM ADJUSTED MAINTENANCE LIVE LOAD SUBROUTINE
3660 FOR I=1 TO 3 STEP 2
3670 ATPS(I)=LFT(I)*SS(I)/12
3680 IF ATPS(I)<=200 THEN R1=1: GOTO 3710
3690 IF ATPS(I)>=600 THEN R1=.6: GOTO 3710
3700 R1=1.2-.001*ATPS(I)
3710 IF PLANGLE(I)<=18 THEN R2=1: GOTO 3740
3720 IF PLANGLE(I)>=45 THEN R2=.6: GOTO 3740
3730 R2=1.2-.6*SIN(FNRAD(PLANGLE(I)))/COS(FNRAD(PLANGLE(I)))
3740 QLR(I)=LR*R1*R2
3750 IF QLR(I)<.6*LR THEN QLR(I)=.6*LR
3760 NEXT I
3770 RETURN
3780 REM PLATE WIND LOADING SUBROUTINE
3790 IF MILES>100 THEN IMPORT=1.07: GOTO 3810
3800 IMPORT=1.11-.0004*MILES
3810 IF H>60 THEN GOTO 4280
3820 REM Wind Loading for Duct Elevations of Less Than 60 Feet Above Ground
3830 IF H<=15 THEN KH=.8: GOTO 3850
3840 KH=.369*H^(2/7)
3850 QH=.00256*KH*(IMPORT*V)^2
3860 FOR I=1 TO 4
3870 IF I<>3 GOTO 3890
3880 IF BOTWIND$='N' THEN QW(3)=0: GOTO 4250
3890 ON I GOTO 3910, 4020, 3910, 4130
3900 REM Wind Loading on Top and Bottom Panels
3910 IF PLANGLE(I)>10 GOTO 3960

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3920     IF SS(I)*LFT(I)/12<10 THEN GCP=-1.4\ GOTO 4220
3930     GCP=-1.4+.2*LOG10(SS(I)*LFT(I)/120)
3940     IF GCP>-1.2 THEN GCP=-1.2
3950     GOTO 4220
3960     IF PLANGLE(I)>30 GOTO 3920
3970     IF SS(I)*LFT(I)/12<10 THEN GCP=-1.3\ GOTO 4220
3980     GCP=-1.3+.2*LOG10(SS(I)*LFT(I)/120)
3990     IF GCP>-1.1 THEN GCP=-1.1
4000     GOTO 4220
4010 REM   Wind Loading on Leeward Side Panel
4020     IF PLANGLE(1)>10 GOTO 4080
4030     IF PLANGLE(3)>10 GOTO 4080
4040     IF SS(I)*LFT(I)/12<10 THEN GCP=-1.35\ GOTO 4220
4050     GCP=-1.35+.212*LOG10(SS(I)*LFT(I)/120)
4060     IF GCP>-.99 THEN GCP=-.99
4070     GOTO 4220
4080     IF SS(I)*LFT(I)/12<10 THEN GCP=-1.5\ GOTO 4220
4090     GCP=-1.5+.235*LOG10(SS(I)*LFT(I)/120)
4100     IF GCP>-1.1 THEN GCP=-1.1
4110     GOTO 4220
4120 REM   Wind Loading on Windward Side Panel
4130     IF PLANGLE(1)>10 GOTO 4190
4140     IF PLANGLE(3)>10 GOTO 4190
4150     IF SS(I)*LFT(I)/12<10 THEN GCP=1.35\ GOTO 4220
4160     GCP=1.35-.265*LOG10(SS(I)*LFT(I)/120)
4170     IF GCP<.9 THEN GCP=.9
4180     GOTO 4220
4190     IF SS(I)*LFT(I)/12<10 THEN GCP=1.5\ GOTO 4220
4200     GCP=1.5-.294*LOG10(SS(I)*LFT(I)/120)
4210     IF GCP<1 THEN GCP=1
4220     QW(I)=QH*GCP
4230     IF ABS(QW(I))>QWMIN GOTO 4250
4240     IF QW(I)>=0 THEN QW(I)=QWMIN ELSE QW(I)=QWMIN*-1
4250 NEXT I
4260 GOTO 4590
4270 REM   Wind Loading for Duct Elevations Over 60 Feet Above the Ground
4280 IF EXPOSURE$='C' THEN KZ=.369*Z^(2/7)\ GOTO 4300
4290 KZ=.696*Z^.2
4300 QZ=.00256*KZ*(IMPORT*U)^2
4310 IF EXPOSURE$='C' THEN KH=.396*H^(2/7)\ GOTO 4330
4320 KH=.696*H^.2
4330 QH=.00256*KH*(IMPORT*U)^2
4340 FOR I=1 TO 4
4350     IF I<>3 GOTO 4370
4360     IF BOTWIND$='N' THEN QW(3)=0\ GOTO 4580
4370     ON I GOTO 4390,4460,4390,4530
4380 REM   Wind Loading on Top and Bottom Panels
4390     IF SS(I)*LFT(I)/12<10 THEN GCP=-2\ GOTO 4420
4400     GCP=-2+LOG10(SS(I)*LFT(I)/120)
4410     IF GCP>-1 THEN GCP=-1
4420     QW(I)=QH*GCP
4430     IF ABS(QW(I))<QWMIN THEN QW(I)=QWMIN*-1
4440     GOTO 4580
4450 REM   Wind Loading on Leeward Side Panel
4460     IF SS(I)*LFT(I)/12<100 THEN GCP=-1.1\ GOTO 4490
4470     GCP=-1.1+.429*LOG10(SS(I)*LFT(I)/1200)

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4480     IF GCP>-.8 THEN GCP=-.8
4490     QW(I)=QH*GCP
4500     IF ABS(QW(I))<QMIN THEN QW(I)=QMIN*-1
4510     GOTO 4580
4520 REM   Wind Loading on Windward Side Panel
4530     IF SS(I)*LFT(I)/12<10 THEN GCP=1.1\ GOTO 4560
4540     GCP=1.1-.206*LOG10(SS(I)*LFT(I)/120)
4550     IF GCP<.75 THEN GCP=.75
4560     QW(I)=QZ*GCP
4570     IF QW(I)<QMIN THEN QW(I)=QMIN
4580 NEXT I
4590 RETURN
4600 REM   SNOW LOADING SUBROUTINE
4610 IF ALASKA$='Y' THEN COEFF=.86 ELSE COEFF=1.01
4620 IF HEAT$='U' THEN CT=1.2 ELSE CT=1
4630 IF PLANGLE(1)>=5 GOTO 4650
4640 QS=COEFF*CE*CT*PG\ GOTO 4730
4650 IF CT=1.2 GOTO 4690
4660 IF PLANGLE(1)<=30 THEN CS=COS(FNRAD(PLANGLE(1)))\ GOTO 4720
4670 IF PLANGLE(1)>70 THEN CS=0\ GOTO 4720
4680 CS=(1-(PLANGLE(1)-30)/40)*COS(FNRAD(PLANGLE(1)))\ GOTO 4720
4690 IF PLANGLE(1)<=45 THEN CS=COS(FNRAD(PLANGLE(1)))\ GOTO 4720
4700 IF PLANGLE(1)>70 THEN CS=0\ GOTO 4720
4710 CS=(1-(PLANGLE(1)-45)/25)*COS(FNRAD(PLANGLE(1)))
4720 QS=COEFF*CS*CE*CT*PG
4730 RETURN
4740 REM   SEISMIC ZONE COEFFICIENT SUBROUTINE
4750 IF SEISZ=0 THEN ZS=1/8\ GOTO 4810
4760 ON SEISZ GOTO 4770,4780,4790,4800
4770 ZS=3/16\ GOTO 4810
4780 ZS=3/8\ GOTO 4810
4790 ZS=3/4\ GOTO 4810
4800 ZS=1
4810 RETURN
4820 REM   DUCT PANEL SEISMIC LOADING SUBROUTINE
4830 GOSUB 4750
4840 FOR I=2 TO 4 STEP 2\QEP(I)=.45*ZS*(UWP*T(I)/12+QDL)\ NEXT I
4850 RETURN
4860 REM   PLATE LOAD DETERMINATION SUBROUTINE - NO WIND OR SEISMIC FORCES
4870 FOR I=1 TO 3 STEP 2\QD(I)=UWP*T(I)/12\ NEXT I
4880 REM   Top Panel
4890 IF INSULLAG$='N' GOTO 4910
4900 Q11=QD(1)+QDL+QLV\Q13=QD(1)+QDL\ GOTO 4920
4910 Q11=QD(1)+QDL+QLV+QLR(1)+QS\Q13=QD(1)+QDL+QLR(1)+QS
4920 Q12=QD(1)+QDL-QLP
4930 IF ABS(Q11)>ABS(Q12) THEN Q(1)=Q11 ELSE Q(1)=Q12
4940 IF ABS(Q13)>ABS(Q(1)) THEN Q(1)=Q13
4950 REM   Side Panels
4960 Q21=QLV\Q22=-QLP-CLA*QLA
4970 IF ABS(Q21)>ABS(Q22) THEN Q(2)=Q21 ELSE Q(2)=Q22
4980 Q(4)=Q(2)
4990 REM   Bottom Panel
5000 Q31=-QD(3)-QDL+QLV\Q32=-QD(3)-QDL-QLP-QLA\Q33=-QD(3)-QDL-QLR(3)-QLA
5010 IF ABS(Q31)>ABS(Q32) THEN Q(3)=Q31 ELSE Q(3)=Q32
5020 IF ABS(Q33)>ABS(Q(3)) THEN Q(3)=Q33
5030 RETURN

```

DUCT2.BAS

23:22

02-Apr-86

```

5040 REM    PLATE LOAD DETERMINATION SUBROUTINE - WITH WIND OR SEISMIC FORCES
5050 FOR I=1 TO 3 STEP 2\QD(I)=UWP*T(I)/12\ NEXT I
5060 REM    Top Panel
5070 QWE(1)=QD(1)+QDL-QLP+QW(1)
5080 REM    Side Panels
5090 IF INSULLAG$='N' GOTO 5110
5100 QWE2(1)=0\QWE2(3)=0\QWE2(5)=0\QWE2(6)=-CLA*QLA\ GOTO 5130
5110 QWE2(1)=QLV+QW(4)\QWE2(3)=-QLP+QW(2)-CLA*QLA
5120 QWE2(5)=QW(4)\QWE2(6)=QW(2)-CLA*QLA
5130 QWE2(2)=QLV+QW(4)
5140 QWE2(4)=-QLP-QEP(4)-CLA*QLA\QWE2(7)=-QEP(2)-CLA*QLA
5150 QWE(2)=QWE2(1)
5160 FOR I=2 TO 7\ IF ABS(QWE2(I))>ABS(QWE(2)) THEN QWE(2)=QWE2(I)\ NEXT I
5170 QWE(4)=QWE(2)
5180 REM    Bottom Panel
5190 IF INSULLAG$='N' GOTO 5210
5200 QWE32=-QD(3)-QDL-QLP-QLA\QWE33=-QD(3)-QDL-QLR(3)-QLA\ GOTO 5220
5210 QWE32=-QD(3)-QDL-QLP-QLA+QW(3)\QWE33=-QD(3)-QDL-QLR(3)-QLA+QW(3)
5220 IF ABS(QWE32)>ABS(QWE33) THEN QWE(3)=QWE32\ GOTO 5240
5230 QWE(3)=QWE33
5240 RETURN
5250 REM    PLATE LOAD DETERMINATION SUBROUTINE - EXCURSION CONDITIONS
5260 FOR I=1 TO 3 STEP 2\QD(I)=UWP*T(I)/12\ NEXT I
5270 REM    Top Panel
5280 IF INSULLAG$='N' GOTO 5300
5290 QX11=QD(1)+QDL+QXV\ GOTO 5310
5300 QX11=QD(1)+QDL+QLR(1)+QS+QXV
5310 QX12=QD(1)+QDL-QXP
5320 IF ABS(QX11)>ABS(QX12) THEN QX(1)=QX11\ GOTO 5350
5330 QX(1)=QX12
5340 REM    Side Panels
5350 QX21=QXV\QX22=-QXP-CLA*QLA
5360 IF ABS(QX21)>ABS(QX22) THEN QX(2)=QX21\ GOTO 5380
5370 QX(2)=QX22
5380 QX(4)=QX(2)
5390 REM    Bottom Panel
5400 QX31=-QD(3)-QDL+QXV\QX32=-QD(3)-QDL-QLA-QXP
5410 IF ABS(QX31)>ABS(QX32) THEN QX(3)=QX31\ GOTO 5430
5420 QX(3)=QX32
5430 RETURN
5440 REM    INTERIOR DUCT PANEL STRESS AND DEFLECTION SUBROUTINE
5450 DEF FNSINH(X)=(EXP(X)-EXP(-X))/2
5460 DEF FNTANH(X)=(EXP(X)-EXP(-X))/(EXP(X)+EXP(-X))
5470 DEF FNCALCU(X)=81/(16*X^7*FNTANH(X))+27/(16*X^6*FNSINH(X)^2)-FNCU1(X)
5480 DEF FNCU1(X)=27/(4*X^8)+9/(8*X^6)-(E^2*PLTHK^8)/((1-PR^2)^2*QQ^2*SSP^8)
5490 DEF FNPSI(X)=(3*(1-FNTANH(X)))/(X^2*FNTANH(X))
5500 DEF FNF1(X)=(24/X^4)*(X^2/2+X/FNSINH(X)-X/FNTANH(X))
5510 LET LOWER=.2\UPPER=44\RANGEFLAG=0
5520 LET TEST=(E^2*PLTHK^8)/((1-PR^2)^2*QQ^2*SSP^8)
5530 IF TEST<.0000000001397 OR TEST>.178 GOTO 5590
5540 FOR I=1 TO 500
5550     LET U=(LOWER+UPPER)/2
5560     IF FNCALCU(LOWER)*FNCALCU(U)<0 THEN UPPER=U ELSE LOWER=U
5570     IF ABS(UPPER-LOWER)<.00005 GOTO 5600
5580 NEXT I
5590 RANGEFLAG=1\ GOTO 5650

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DUCT2.BAS

23:22

02-Apr-86

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5600 LET STRESS1=((E*U^2)/(3*(1-PR^2)))*(PLTHK/SSP)^2/1000
5610 LET STRESS2=((QQ/2)*(SSP/PLTHK)^2*FNPSI(U))/1000
5620 LET MAXSTR=(STRESS1+STRESS2)*1000
5630 LET D=(E*PLTHK^3)/(12*(1-PR^2))
5640 LET MAXDFL=(QQ*SSP^4*FNFI(U))/(384*D)
5650 RETURN
5660 REM    STRESS AND DEFLECTION TABLE SUBROUTINE
5670 FOR JJ=1 TO 6
5680     GOSUB 5450
5690     IF RANGEFLAG=0 GOTO 5720
5700     RNGFLG(JJ)=1
5710     GOTO 5740
5720     STRANDDFL(1,JJ)=MAXSTR/1000
5730     STRANDDFL(2,JJ)=MAXDFL
5740     PLTHK=PLTHK+.0625
5750 NEXT JJ
5760 RETURN
5770 REM    PLATE STRESS PRINT SUBROUTINE
5780 FOR JJ=1 TO 6
5790     IF RNGFLG(JJ)=0 GOTO 5820
5800     PRINT USING "I 'LLLL ",RANGE$;
5810     GOTO 5840
5820     IF STRESS1/LIMITA+STRESS2/LIMITB>1 THEN STFL$='*' ELSE STFL$=' '
5830     PRINT USING "I ###.## ",STRANDDFL(1,JJ);STFL$;
5840 NEXT JJ\ PRINT
5850 RETURN
5860 REM    PLATE DEFLECTION PRINT SUBROUTINE
5870 FOR JJ=1 TO 6
5880     IF RNGFLG(JJ)=0 GOTO 5910
5890     PRINT USING "I 'LLLL ",RANGE$;
5900     GOTO 5930
5910     IF STRANDDFL(2,JJ)>LIMITD THEN DFLFLG$='*' ELSE DFLFLG$=' '
5920     PRINT USING "I ##.## ",STRANDDFL(2,JJ);DFLFLG$;
5930 NEXT JJ\ PRINT
5940 RETURN

```

DUCT3.BAS

15:51

12-Mar-86

```

SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT3
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO ESTABLISH FURTHER DESIGN PARAMETERS
40 REM   TO BE USED IN THE STRUCTURAL DESIGN OF TRANSVERSE STIFFENERS FOR A
50 REM   HORIZONTAL SECTION OF COAL-FUELED POWER PLANT DUCTWORK
60 REM
70 PROGRAM DUCT3
80 LET I3=3\I4=4
90 DIM DSA(I3),WELD$(I4),LBRC(I4),WA(I4),LY(I4),LFT(I4),PLANGLE(I3),SS(I4)
100 OPEN 'LP:' FOR OUTPUT AS FILE #1
110 OPEN 'DATA2' FOR INPUT AS FILE #2\ OPEN 'DATA5' FOR INPUT AS FILE #5
120 INPUT #2,INSULLAG$,LR,LSPAN,QLA,PLANGLE(1),PLANGLE(3)
130 INPUT #2,LFT(1),LFT(2),LFT(3),LFT(4)
140 INPUT #5,SS(1),SS(2),SS(3),SS(4)
150 CLOSE #2,#5
160 DEF FNRAD(DEG)=DEG*(PI/180)\ PRINT \ PRINT
170 PRINT 'DO YOU WANT A HARD COPY OF THE STIFFENER SELECTION OUTPUT? (Y OR N)'
180 INPUT HCOPY$\ PRINT
190 IF HCOPY$='N' THEN PRINT CHR$(27)+'[?4i'\ GOTO 210
200   PRINT CHR$(27)+'[?5i'
210 PRINT \ PRINT \ PRINT TAB(25);'TRANSVERSE STIFFENER DESIGN'\ PRINT \ PRINT
220 PRINT 'YOU MAY ELECT TO DESIGN THE TRANSVERSE STIFFENERS AS PINNED-END ' ;
230 PRINT 'BEAM COLUMNS,'\ PRINT 'OR AS A RIGID FRAME ENCIRCLING THE DUCT. ' ;
240 PRINT 'IF YOU WISH TO EXECUTE THE PINNED-END'\ PRINT 'STIFFENER DESIGN ' ;
250 PRINT 'PROGRAM ENTER P.  IF YOU WISH TO EXECUTE THE RIGID FRAME'
260 PRINT 'STIFFENER DESIGN PROGRAM ENTER R.'
270 INPUT CONN$\ PRINT \ IF CONN$='P' GOTO 440
280 FLAG=0\ FOR I=1 TO 3\ IF SS(I)<>SS(I+1) THEN FLAG=1
290 NEXT I\ IF FLAG=0 GOTO 440
300 PRINT 'STIFFENER SPACINGS FOR ALL FOUR SIDES OF THE DUCT MUST BE EQUAL IF';
310 PRINT ' RIGID FRAME'\ PRINT 'STIFFENERS ARE USED.  THE STIFFENER SPACINGS';
320 PRINT ' THAT YOU HAVE SELECTED ARE NOT ALL'\ PRINT 'EQUAL.'\ PRINT \ PRINT
330 PRINT 'DO YOU WISH TO CHANGE THE STIFFENER SPACINGS PREVIOUSLY SELECTED? ' ;
340 PRINT ' (Y OR N)'\ INPUT CHNG$\ PRINT \ IF CHNG$='N' GOTO 420
350 PRINT 'NOTE:  IN ORDER TO ENSURE THAT THESE DIFFERENT STIFFENER SPACINGS ' ;
360 PRINT 'DO NOT LEAD'\ PRINT 'TO EXCESSIVE PLATE STRESSES OR DEFLECTIONS, ' ;
370 PRINT 'THE STRESS AND DEFLECTION TABLES'\ PRINT 'GENERATED IN PROGRAM ' ;
380 PRINT 'DUCT2 (UNDER OPTION 1) MAY BE CHECKED, OR PROGRAM DUCT2'
390 PRINT 'MAY BE REEXECUTED.'\ PRINT
400 FOR I=1 TO 4\ PRINT 'ENTER THE STIFFENER SPACING FOR SIDE';I;'IN INCHES'
410   INPUT SS(I)\ PRINT \ NEXT I\ GOTO 280
420 PRINT \ PRINT 'THE TRANSVERSE STIFFENERS WILL BE DESIGNED USING THE PIN';
430 PRINT 'NED-END STIFFENER'\ PRINT 'DESIGN PROGRAM'\ PRINT \ PRINT \ CONN$='P'
440 PRINT 'ENTER THE STIFFENER YIELD STRESS IN KSI'
450 INPUT FYS\ PRINT
460 PRINT 'ENTER THE MODULUS OF ELASTICITY OF THE STIFFENERS IN KSI'
470 INPUT ES\ PRINT
480 PRINT 'ENTER THE UNIT WEIGHT OF THE STIFFENERS IN PCF'
490 INPUT UWS\ PRINT
500 PRINT 'ENTER THE MAXIMUM ALLOWABLE STIFFENER DEFLECTION FOR NORMAL OPERAT';
510 PRINT 'ING CONDITIONS'\ PRINT 'ENTER XXX, WHERE MAXIMUM ALLOWABLE DEFLECTI';
520 PRINT 'ON = STIFFENER SPAN/XXX'\ PRINT '(SUGGESTED VALUE FOR XXX IS 240)'
530 INPUT DSA(1)\ PRINT
540 PRINT 'DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE STIFFENER DEFLECTION UN';
550 PRINT 'DER WIND OR'\ PRINT 'SEISMIC FORCES? (Y OR N)'

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DUCT3.BAS

15:51

12-Mar-86

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560 INPUT PROMPT2$ \ PRINT
570 IF PROMPT2$='N' THEN DSA(2)=1 \ GOTO 630
580 PRINT 'ENTER THE MAXIMUM ALLOWABLE STIFFENER DEFLECTION UNDER';
590 PRINT ' WIND OR SEISMIC FORCES:'
600 PRINT 'ENTER XXX, WHERE MAXIMUM ALLOWABLE DEFLECTION = STIFFENER SPAN/X';
610 PRINT 'XX'
620 INPUT DSA(2) \ PRINT
630 PRINT 'DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE STIFFENER DEFLECTION UN';
640 PRINT 'DER EXCURSION' \ PRINT 'CONDITIONS? (Y OR N)'
650 INPUT PROMPT3$ \ PRINT
660 IF PROMPT3$='N' THEN DSA(3)=1 \ GOTO 720
670 PRINT 'ENTER THE MAXIMUM ALLOWABLE STIFFENER DEFLECTION UNDER EXCURSION';
680 PRINT ' CONDITIONS'
690 PRINT 'ENTER XXX, WHERE MAXIMUM ALLOWABLE DEFLECTION = STIFFENER SPAN/X';
700 PRINT 'XX'
710 INPUT DSA(3) \ PRINT
720 PRINT 'ENTER THE APPROXIMATE WEIGHT OF INTERNAL BRACING IN THE DUCT SPAN';
730 PRINT ' IN POUNDS'
740 INPUT WB \ PRINT
750 IF HCOPI$='N' GOTO 770
760 PRINT CHR$(27)+'[?4i' \ PRINT #1,CHR$(12) \ PRINT CHR$(27)+'[?5i'
770 IF INSULLAG$='N' THEN QDI=0 \ GOTO 800
780 PRINT 'ENTER THE WEIGHT OF THE DUCT INSULATION AND LAGGING IN PSF'
790 INPUT QDI \ PRINT
800 PRINT 'WHAT SHAPE STIFFENERS DO YOU WISH TO USE? (W = W SHAPE, WT = STRU';
810 PRINT 'CTURAL TEE, \ PRINT 'C = CHANNEL)'
820 INPUT SHP$ \ PRINT
830 IF SHP$='W' THEN SHP=1 ELSE SHP=0
840 IF SHP$='WT' THEN SHP=2
850 IF SHP$='C' THEN SHP=3
860 IF SHP=0 GOTO 800
870 PRINT 'SMALLER STIFFENER SECTIONS MAY RESULT IF THE STIFFENERS ARE CONNE';
880 PRINT 'CTED TO THE' \ PRINT 'DUCT PLATE WITH CONTINUOUS WELDS.' \ PRINT
890 FOR I=1 TO 4
900 PRINT 'WILL THE STIFFENERS ON SIDE';I;'BE CONTINUOUSLY OR INTERMITTENT';
910 PRINT 'LY WELDED TO THE' \ PRINT 'DUCT PLATE? (I = INTERMITTENT WELDS, ';
920 PRINT 'C = CONTINUOUS WELD)'
930 INPUT WELD$(I) \ PRINT
940 NEXT I
950 IF HCOPI$='N' GOTO 970
960 PRINT CHR$(27)+'[?4i' \ PRINT #1,CHR$(12) \ PRINT CHR$(27)+'[?5i'
970 PRINT 'SMALLER STIFFENER SECTIONS MAY RESULT IF THE EXTERIOR FLANGES';
980 PRINT ' (FLANGES NOT' \ PRINT 'IN CONTACT WITH DUCT PLATE) ARE BRACED ';
990 PRINT 'AGAINST TWIST OR LATERAL DISPLACEMENT.' \ PRINT 'SUCH BRACING MAY';
1000 PRINT ' BE PROVIDED BY WELDING STRAPS OR BARS PARALLEL TO THE'
1010 PRINT 'LONGITUDINAL DIRECTION OF THE DUCT TO THE EXTERIOR FLANGE OF EACH ';
1020 PRINT 'TRANSVERSE' \ PRINT 'STIFFENER.' \ PRINT
1030 FOR I=1 TO 4
1040 PRINT 'WILL INTERMEDIATE BRACING AGAINST TWIST OR LATERAL DISPLACEMENT';
1050 PRINT ' OF THE EXTERIOR' \ PRINT 'STIFFENER FLANGES ON SIDE';I;'BE PROV';
1060 PRINT 'IDED? (Y OR N)'
1070 INPUT LBRACE$ \ PRINT
1080 IF LBRACE$='N' THEN LBRC(I)=LFT(I)*12 \ PRINT \ GOTO 1120
1090 PRINT 'WHAT IS THE MAXIMUM UNBRACED LENGTH IN INCHES OF THE EXTERI';
1100 PRINT 'OR STIFFENER FLANGES' \ PRINT 'ON SIDE';I;'?'
1110 INPUT LBRC(I) \ PRINT

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DUCT3.BAS

15:52

12-Mar-86

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1120 NEXT I
1130 REM 3X3X1/4 corner angles are assumed as an initial estimate
1140 FOR I=1 TO 4
1150 WA(I)=4.9\LY(I)=3
1160 NEXT I
1170 REM Calculate adjusted maintenance live load for duct section design
1180 GOSUB 1370
1190 REM Calculate adjusted ash live load
1200 GOSUB 1470
1210 LET C$=',\ OPEN 'DATA4' FOR OUTPUT AS FILE #4
1220 OPEN 'DATA5' FOR OUTPUT AS FILE #5
1230 PRINT #4,HCOPY$;C$;QDI;C$;SHP;C$;UWS;C$;FYS;C$;ES;C$;QLRD;C$;QLAD;C$;WB
1240 PRINT #4,LBRC(1);C$;LBRC(2);C$;LBRC(3);C$;LBRC(4);C$;WA(1);C$;WA(2)
1250 PRINT #4,WA(3);C$;WA(4);C$;DSA(1);C$;DSA(2);C$;DSA(3);C$;LY(1);C$;LY(2)
1260 PRINT #4,LY(3);C$;LY(4);C$;WELD$(1);C$;WELD$(2);C$;WELD$(3);C$;WELD$(4)
1270 PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)
1280 CLOSE #1,#4,#5\ LET IO=0
1290 DIM DSA(IO),WELD$(IO),LBRC(IO),WA(IO),LY(IO),LFT(IO),PLANGLE(IO),SS(IO)
1300 PRINT CHR$(27)+'[?4i'
1310 IF CONN$='R' GOTO 1340
1320 PRINT 'CHAINING TO PROGRAM DUCT4; PLEASE WAIT'
1330 CHAIN 'DUCT4'
1340 PRINT 'CHAINING TO PROGRAM DUCT5; PLEASE WAIT'
1350 RECALC=0\ CHAIN 'DUCT5' WITH RECALC
1360 REM DUCT SECTION ADJUSTED MAINTENANCE LIVE LOAD SUBROUTINE
1370 IF LSPAN*LFT(1)<=100 THEN R1=1\ GOTO 1400
1380 IF LSPAN*LFT(1)>=500 THEN R1=.2\ GOTO 1400
1390 R1=1.2-.002*LSPAN*LFT(1)
1400 IF PLANGLE(1)<=18 THEN R2=1\ GOTO 1430
1410 IF PLANGLE(1)>=45 THEN R2=.6\ GOTO 1430
1420 R2=1.2-.6*SIN(FNRAD(PLANGLE(1)))/COS(FNRAD(PLANGLE(1)))
1430 QLRD=LR*R1*R2
1440 IF QLRD<=.2*LR THEN QLRD=.2*LR
1450 RETURN
1460 REM ADJUSTED ASH LIVE LOAD SUBROUTINE
1470 IF LSPAN*LFT(3)<=100 THEN R3=1\ GOTO 1500
1480 IF LSPAN*LFT(3)>=600 THEN R3=.5\ GOTO 1500
1490 R3=1.1-.001*LSPAN*LFT(3)
1500 QLAD=QLA*R3
1510 RETURN
```

DUCT4.BAS

23:25

02-Apr-86

```

SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT4
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO SELECT TRANSVERSE PINNED-END
40 REM   STIFFENERS
50 REM
60 PROGRAM DUCT4
70 LET I2=2\I3=3\I4=4
80 DIM WES(I4),WS(I4),W(I4,I3,I2),QD(I4)
90 DIM WELD$(I4),LBRC(I4),FB(I3,I2),FBM(I3,I3,I2),WW(I3,I2)
100 DIM WA(I4),DALLOW(I3),LY(I4),AST(I4),SEC$(I4)
110 DIM LFT(I4),PLANGLE(I3),T(I4),SS(I4),QW(I4),QLR(I3),BE(I4)
120 DIM DST(I4),Y1(I4),IE(I4),RE(I4),BF(I4),TF(I4),TW(I4),RT(I4),AE(I4),IXS(I4)
130 DIM PVP(I4,I2,I2),FAM(I4,I2,I2),P(I4,I2),DSA(I3)
140 OPEN 'LP:' FOR OUTPUT AS FILE #1\ OPEN 'DATA3' FOR INPUT AS FILE #3
150 OPEN 'DATA4' FOR INPUT AS FILE #4\ OPEN 'DATA5' FOR INPUT AS FILE #5
160 INPUT #3,CLA,CORR$,CRA,LSPAN,EP,FYP,SEISZ
170 INPUT #3,UMP,QDL,QLA,QLP,QLV,QS,QXP,QXV
180 INPUT #3,LFT(1),LFT(2),LFT(3),LFT(4),QLR(1),QLR(3)
190 INPUT #3,T(1),T(2),T(3),T(4),QW(1),QW(2),QW(3),QW(4)
200 INPUT #4,HCOPY$,QDI,SHP,UWS,FYS,ES,QLRD,QLAD,WB
210 INPUT #4,LBRC(1),LBRC(2),LBRC(3),LBRC(4),WA(1),WA(2)
220 INPUT #4,WA(3),WA(4),DSA(1),DSA(2),DSA(3),LY(1),LY(2)
230 INPUT #4,LY(3),LY(4),WELD$(1),WELD$(2),WELD$(3),WELD$(4)
240 INPUT #5,SS(1),SS(2),SS(3),SS(4)
250 CLOSE #3,#4,#5
260 IF HCOPY$='N' GOTO 280
270 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
280 PRINT \ PRINT \ PRINT TAB(25);'PINNED-END STIFFENER DESIGN'\ PRINT \ PRINT
290 AVAIL=0
300 PRINT 'ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS'
310 PRINT '(REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED '
320 PRINT 'TO HAVE THE'\ PRINT 'SAME NOMINAL DEPTH)'
330 INPUT TRIALND\ PRINT
340 REM   Test to insure that chosen trial nominal depth is available
350 ON SHP GOTO 360,400,450
360 IF TRIALND=6 OR TRIALND=8 OR TRIALND=10 THEN AVAIL=1\ GOTO 480
370 IF TRIALND=12 OR TRIALND=14 OR TRIALND=16 THEN AVAIL=1\ GOTO 480
380 IF TRIALND=18 OR TRIALND=21 OR TRIALND=24 THEN AVAIL=1\ GOTO 480
390 GOTO 480
400 IF TRIALND=3 OR TRIALND=4 OR TRIALND=5 THEN AVAIL=1\ GOTO 480
410 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 480
420 IF TRIALND=9 OR TRIALND=10.5 OR TRIALND=12 THEN AVAIL=1\ GOTO 480
430 IF TRIALND=13.5 OR TRIALND=15 OR TRIALND=16.5 THEN AVAIL=1\ GOTO 480
440 GOTO 480
450 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 480
460 IF TRIALND=9 OR TRIALND=10 OR TRIALND=12 THEN AVAIL=1\ GOTO 480
470 IF TRIALND=15 THEN AVAIL=1
480 IF AVAIL=1 GOTO 580
490 PRINT \ PRINT 'THE TRIAL NOMINAL DEPTH THAT YOU HAVE CHOSEN IS NOT '
500 PRINT 'AVAILABLE IN THIS DESIGN'\ PRINT 'PROGRAM FOR THE STIFFENER '
510 PRINT 'SECTION SHAPE THAT YOU SELECTED PREVIOUSLY. IF YOU'
520 PRINT 'WISH TO CHANGE THE STIFFENER SECTION SHAPE (W SHAPE, WT OR '
530 PRINT 'CHANNEL), YOU MUST\ PRINT 'INTERRUPT THIS PROGRAM (PRESS '
540 PRINT 'Interrupt - Do KEYS), AND RELOAD AND RERUN PROGRAM'
550 PRINT 'DUCT3. OTHERWISE, PLEASE ENTER A DIFFERENT TRIAL NOMINAL '

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AD-A171 769

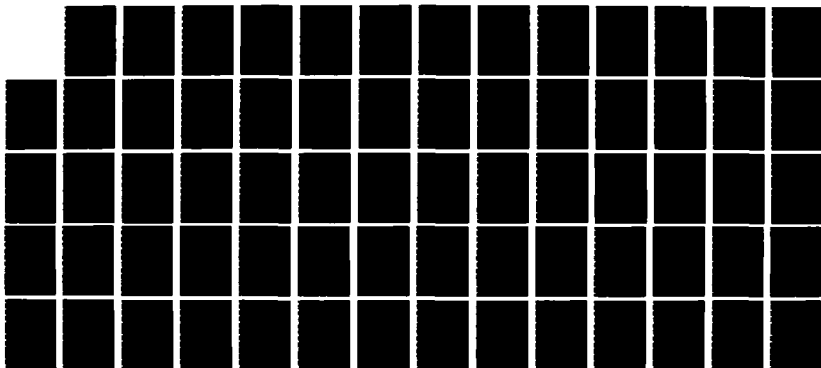
STRUCTURAL DESIGN OF COAL-FUELED POWER PLANT DUCTWORK  
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH  
S P RADER 1986 AFIT/CI/NR-86-1530

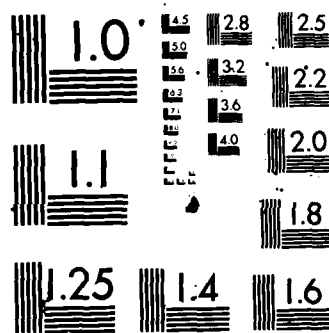
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MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

DUCT4.BAS

15:00

04-Apr-86

```

560 PRINT 'DEPTH.'
570 GOTO 260
580 IF HCOPY$='N' GOTO 600
590 PRINT CHR$(27)+'[?4i'
600 PRINT 'TRANSVERSE STIFFENERS ARE BEING SELECTED; PLEASE WAIT'
610 IF HCOPY$='N' GOTO 630
620 PRINT CHR$(27)+'[?5i'
630 FOR I=1 TO 4\SEC$(I)='*****'\WS(I)=0\ NEXT I
640 MAXWT=0
650 ON SHP GOTO 660,670,680
660 OPEN 'WSHAPE' FOR INPUT AS FILE #10\ GOTO 700
670 OPEN 'WT' FOR INPUT AS FILE #10\ GOTO 700
680 OPEN 'C' FOR INPUT AS FILE #10
690 REM End of File Check
700 IF MAXWT=1 THEN CLOSE #10\ GOTO 1360
710 REM Read W, WT, or Channel shape properties
720 ON SHP GOTO 730,740,750
730 GOSUB 1980\ GOTO 760
740 GOSUB 2130\ GOTO 760
750 GOSUB 2270
760 IF NDST<>TRIALND GOTO 720
770 REM Check to see if section is heaviest possible section for that
780 REM nominal depth
790 IF MAXND=TRIALND THEN MAXWT=1
800 REM Calculate effective section properties
810 FOR I=1 TO 4\ IF SEC$(I)<>'*****' GOTO 820 ELSE GOSUB 2410
820 NEXT I
830 REM Calculate trial stiffener weights
840 FOR I=1 TO 4\ IF SEC$(I)='*****' THEN WS(I)=AST*UWS/144
850 NEXT I
860 REM Execute stiffener transverse loading subroutines
870 GOSUB 2520\ GOSUB 2680
880 REM Calculate axial stresses and forces in stiffeners
890 GOSUB 3150
900 FOR II=1 TO 4
910 IF SEC$(II)<>'*****' GOTO 1090
920 REM Calculate maximum stiffener and plate bending stresses
930 FOR J=1 TO 3\ FOR K=1 TO 2\W(J,K)=W(II,J,K)\ NEXT K\ NEXT J
940 GOSUB 3580
950 REM Calculate allowable stiffener and plate axial compressive stress
960 GOSUB 3710
970 REM Calculate allowable stiffener and plate bending stresses
980 GOSUB 3810
990 REM Check interaction formulas
1000 GOSUB 4210\ IF FLAG=1 GOTO 1090
1010 REM Check stiffener deflections
1020 GOSUB 5170\ IF FLAG=1 GOTO 1090
1030 REM Check stiffener moment of inertia and gross area requirements
1040 REM (vertical stiffeners only)
1050 IF II=1 OR II=3 GOTO 1070
1060 GOSUB 5420\ IF FLAG=1 GOTO 1090
1070 SEC$(II)=SECT$WS(II)=AST*UWS/144\DST(II)=DST\AST(II)=AST
1080 BF(II)=BF\TF(II)=TF\TW(II)=TW\RT(II)=RT\IXS(II)=IXS\YS(II)=YS
1090 NEXT II
1100 FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)='*****' THEN FLAG=1
1110 NEXT I\ IF FLAG=1 GOTO 700

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1120 CLOSE #10
1130 REM Check Vertical Stiffeners Using Actual Stiffener Weights
1140 REM Recalculate axial stresses and forces in vertical stiffeners
1150 GOSUB 3150
1160 FOR II=2 TO 4 STEP 2
1170 REM Recalculate maximum stiffener and plate bending stresses
1180 DST=DST(II)
1190 FOR J=1 TO 3\ FOR K=1 TO 2\WW(J,K)=W(II,J,K)\ NEXT K\ NEXT J
1200 GOSUB 3580
1210 REM Recalculate allowable stiffener and plate axial compressive stress
1220 BF=BF(II)\TF=TF(II)\ GOSUB 3710
1230 REM Recalculate allowable stiffener and plate bending stresses
1240 TW=TW(II)\RT=RT(II)\ GOSUB 3810
1250 REM Recheck interaction formulas
1260 GOSUB 4210\ IF FLAG=1 GOTO 1320
1270 REM Recheck vertical stiffener deflections
1280 GOSUB 5170\ IF FLAG=1 GOTO 1320
1290 REM Recheck stiffener moment of inertia and gross area requirements
1300 IXS=IXS(II)\AST=AST(II)\YS=YS(II)\ GOSUB 5420\ IF FLAG=1 GOTO 1320
1310 GOTO 1330
1320 SEC$(II)='*****'
1330 NEXT II
1340 FLAG=0\ FOR I=2 TO 4 STEP 2\ IF SEC$(I)='*****' THEN FLAG=1
1350 NEXT I\ IF FLAG=1 GOTO 640
1360 PRINT \ PRINT TAB(38);'PINNED-END STIFFENERS'\ PRINT
1370 PRINT TAB(23);'SIDE 1';TAB(38);'SIDE 2';TAB(53);'SIDE 3';TAB(68);'SIDE 4'
1380 PRINT \ PRINT 'STIFFENER SPACING';TAB(25);SS(1);TAB(40);SS(2);TAB(55);
1390 PRINT SS(3);TAB(70);SS(4)\ PRINT ' (INCHES)'
1400 PRINT 'STIFFENER SECTION';TAB(21);
1410 FOR I=1 TO 4\ PRINT USING "CCCCCCCCC ",SEC$(I);\ NEXT I
1420 PRINT \ PRINT \ PRINT
1430 FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)='*****' THEN FLAG=1
1440 NEXT I\ IF FLAG=1 GOTO 1460
1450 GOTO 1500
1460 PRINT 'NOTE: "*****" INDICATES THAT AN ADEQUATE PINNED-END STIFFENER '
1470 PRINT 'SECTION WITH'\ PRINT TAB(6);TRIALND;'INCH NOMINAL DEPTH DOES NOT '
1480 PRINT 'EXIST. YOU MUST SELECT STIFFENER'\ PRINT TAB(7);'SECTIONS WITH '
1490 PRINT 'A GREATER NOMINAL DEPTH.'\ PRINT \ PRINT
1500 PRINT 'DO YOU WISH TO SELECT PINNED-END STIFFENERS WITH A DIFFERENT NOMI'
1510 PRINT 'NAL DEPTH?'\ PRINT '(ENTER Y OR N)'
1520 INPUT DIFF$\ PRINT \ PRINT
1530 PRINT 'DO YOU WISH TO SELECT DIFFERENT STIFFENER SPACINGS? (Y OR N)'
1540 INPUT DIFSTIFF$\ PRINT \ PRINT \ IF DIFSTIFF$='N' GOTO 1630
1550 PRINT 'NOTE: THIS PROGRAM DOES NOT RECHECK MAXIMUM PLATE STRESSES AND '
1560 PRINT 'DEFLECTIONS'\ PRINT 'ASSOCIATED WITH THE CHANGED STIFFENER SPAC'
1570 PRINT 'INGS. THIS CHECK MAY BE ACCOMPLISHED'\ PRINT 'BY EITHER REFERRING'
1580 PRINT ' TO THE STRESS-DEFLECTION TABLES GENERATED IN PROGRAM DUCT2'
1590 PRINT '(UNDER OPTION 1), OR BY REEXECUTING PROGRAM DUCT2 WITH THE REVIS'
1600 PRINT 'ED STIFFENER'\ PRINT 'SPACINGS.'\ PRINT
1610 FOR I=1 TO 4\ PRINT 'ENTER THE STIFFENER SPACING FOR SIDE';I;'IN INCHES'
1620 INPUT SS(I)\ PRINT \ NEXT I\ GOTO 260
1630 IF DIFF$='Y' GOTO 260
1640 PRINT 'DO YOU WISH TO EXECUTE THE RIGID FRAME STIFFENER DESIGN PROGRAM?';
1650 PRINT ' (Y OR N)\ INPUT RIGID$\ PRINT
1660 IF RIGID$='N' GOTO 1860
1670 FLAG=0\ FOR I=1 TO 3\ IF SS(I)<>SS(I+1) THEN FLAG=1

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1680 NEXT I\ IF FLAG=0 GOTO 1860
1690 PRINT 'STIFFENER SPACINGS FOR ALL FOUR SIDES OF THE DUCT MUST BE EQUAL IF';
1700 PRINT ' RIGID FRAME'\ PRINT 'STIFFENERS ARE USED. THE STIFFENER SPACINGS';
1710 PRINT ' THAT YOU HAVE SELECTED ARE NOT ALL'\ PRINT 'EQUAL.'\ PRINT \ PRINT
1720 PRINT 'DO YOU WISH TO CHANGE THE STIFFENER SPACINGS PREVIOUSLY SELECTED? ';
1730 PRINT ' (Y OR N)'\ INPUT CHNG%\ PRINT \ IF CHNG$='N' GOTO 1830
1740 PRINT 'NOTE: IN ORDER TO ENSURE THAT THESE DIFFERENT STIFFENER SPACINGS ';
1750 PRINT 'DO NOT LEAD'\ PRINT 'TO EXCESSIVE PLATE STRESSES OR DEFLECTIONS, ';
1760 PRINT 'THE STRESS AND DEFLECTION TABLES'\ PRINT 'GENERATED IN PROGRAM ';
1770 PRINT 'DUCT2 (UNDER OPTION 1) MAY BE CHECKED, OR PROGRAM DUCT2'
1780 PRINT 'MAY BE REEXECUTED.'
1790 IF HCOPY$='N' GOTO 1810
1800 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
1810 FOR I=1 TO 4\ PRINT 'ENTER THE STIFFENER SPACING FOR SIDE';I;'IN INCHES'
1820 INPUT SS(I)\ PRINT \ NEXT I\ GOTO 1670
1830 PRINT 'THE RIGID FRAME STIFFENER DESIGN PROGRAM WILL NOT BE EXECUTED. ';
1840 PRINT ' DUCT SECTION'\ PRINT 'CHECKS WILL NOW BE ACCOMPLISHED.'
1850 RIGID$='N'
1860 C$=', '\ OPEN 'DATA5' FOR OUTPUT AS FILE #5
1870 PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #1,#5\ I0=0
1880 DIM WES(10),WS(10),W(10,10,10),QD(10),WA(10),DALLOW(10),LY(10),AST(10)
1890 DIM WELD$(10),LBRC(10),FB(10,10),FBM(10,10,10),WW(10,10),SEC$(10),IXS(10)
1900 DIM LFT(10),PLANGLE(10),T(10),SS(10),QW(10),QLR(10),BE(10)
1910 DIM DST(10),Y1(10),IE(10),RE(10),BF(10),TF(10),TW(10),RT(10),AE(10)
1920 DIM PVP(10,10,10),FAM(10,10,10),P(10,10),DSA(10)
1930 PRINT CHR$(27)+'[?4i'\ IF RIGID$='Y' GOTO 1950
1940 PRINT 'CHAINING TO PROGRAM DUCT7; PLEASE WAIT'\ CHAIN 'DUCT7'
1950 RECALC=0\ PRINT 'CHAINING TO PROGRAM DUCT5; PLEASE WAIT'
1960 CHAIN 'DUCT5' WITH RECALC
1970 REM W SHAPE PROPERTY RETRIEVAL SUBROUTINE
1980 LINPUT #10,WSHAPE1%\ LINPUT #10,WSHAPE2%
1990 LINPUT #10,WSHAPE3%\ LINPUT #10,WSHAPE4%
2000 SECT$=MID$(WSHAPE1$,1%,7%)
2010 AST=VAL(MID$(WSHAPE1$,15%,6%))
2020 DST=VAL(MID$(WSHAPE1$,29%,5%))
2030 NDST=VAL(MID$(WSHAPE1$,42%,2%))
2040 MAXND=VAL(MID$(WSHAPE1$,53%,2%))
2050 TW=VAL(MID$(WSHAPE1$,56%,4%))
2060 BF=VAL(MID$(WSHAPE1$,68%,5%))
2070 TF=VAL(MID$(WSHAPE2$,6%,5%))
2080 RT=VAL(MID$(WSHAPE2$,45%,4%))
2090 IXS=VAL(MID$(WSHAPE2$,54%,7%))
2100 YS=DST/2
2110 RETURN
2120 REM WT PROPERTY RETRIEVAL SUBROUTINE
2130 LINPUT #10,WT1%\ LINPUT #10,WT2%\ LINPUT #10,WT3%
2140 SECT$=MID$(WT1$,1%,12%)
2150 AST=VAL(MID$(WT1$,18%,5%))
2160 DST=VAL(MID$(WT1$,31%,5%))
2170 NDST=VAL(MID$(WT1$,44%,4%))
2180 MAXND=VAL(MID$(WT1$,53%,4%))
2190 TW=VAL(MID$(WT1$,58%,4%))
2200 BF=VAL(MID$(WT1$,70%,5%))
2210 TF=VAL(MID$(WT2$,6%,5%))
2220 RT=VAL(MID$(WT2$,45%,4%))
2230 IXS=VAL(MID$(WT2$,56%,6%))

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2240 YS=VAL(MID$(WT3$,19%,5%))
2250 RETURN
2260 REM CHANNEL PROPERTY RETRIEVAL SUBROUTINE
2270 LINPUT #10,C1$\ LINPUT #10,C2$\ LINPUT #10,C3$
2280 SECT$=MID$(C1$,1%,8%)
2290 AST=VAL(MID$(C1$,18%,5%))
2300 DST=VAL(MID$(C1$,31%,5%))
2310 NDST=VAL(MID$(C1$,31%,2%))
2320 MAXND=VAL(MID$(C1$,41%,2%))
2330 TW=VAL(MID$(C1$,46%,4%))
2340 BF=VAL(MID$(C1$,58%,5%))
2350 TF=VAL(MID$(C1$,72%,4%))
2360 IXS=VAL(MID$(C2$,56%,6%))
2370 YS=DST/2
2380 RETURN
2390 REM STIFFENER EFFECTIVE SECTION PROPERTIES SUBROUTINE
2400 REM Determine the effective plate width, BE(I)
2410 BE(I)=1.5*T(I)*SQR(EP/FYP)
2420 REM Determine area of combined stiffener and effective plate, AE(I)
2430 AE(I)=AST+BE(I)*T(I)
2440 REM Determine the distance to the effective centroidal axis, Y1(I)
2450 Y1(I)=(AST*YS+BE(I)*T(I)*(DST+T(I)/2))/AE(I)
2460 REM Determine the effective moment of inertia, IE(I)
2470 IE(I)=IXS+AST*(Y1(I)-YS)^2+BE(I)*T(I)*(T(I)^2/12+(DST+T(I)/2-Y1(I))^2)
2480 REM Determine the effective radius of gyration, RE(I)
2490 RE(I)=SQR(IE(I)/AE(I))
2500 RETURN
2510 REM STIFFENER SEISMIC LOADING SUBROUTINE
2520 GOSUB 2600
2530 IF CORR$='N' GOTO 2550
2540 FOR I=2 TO 4 STEP 2\T(I)=T(I)+CRA\ NEXT I
2550 FOR I=2 TO 2 STEP 2\WES(I)=.45*ZS*((UWP*T(I)/12+QDL+QDI)*SS(I)/12+WS(I))
2560 NEXT I\ IF CORR$='N' GOTO 2580
2570 FOR I=2 TO 4 STEP 2\T(I)=T(I)-CRA\ NEXT I
2580 RETURN
2590 REM SEISMIC ZONE COEFFICIENT SUBROUTINE
2600 IF SEISZ=0 THEN ZS=1/8\ GOTO 2660
2610 ON SEISZ GOTO 2620,2630,2640,2650
2620 ZS=3/16\ GOTO 2660
2630 ZS=3/8\ GOTO 2660
2640 ZS=3/4\ GOTO 2660
2650 ZS=1
2660 RETURN
2670 REM PINNED-END STIFFENER TRANSVERSE LOAD DETERMINATION SUBROUTINE
2680 IF CORR$='N' GOTO 2700
2690 FOR I=1 TO 3 STEP 2\T(I)=T(I)+CRA\ NEXT I
2700 FOR I=1 TO 3 STEP 2\QD(I)=UWP*T(I)/12\ NEXT I
2710 REM Pinned-End: No Wind or Seismic Forces
2720 REM Top Stiffener
2730 W(1,1,1)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS)*SS(1)/12+WS(1)
2740 W(1,1,2)=(QD(1)+QDL+QDI-QLP)*SS(1)/12+WS(1)
2750 REM Side Stiffeners
2760 FOR I=2 TO 4 STEP 2
2770 W(1,1,1)=QLV*SS(I)/12\W(1,1,2)=(-QLP-CLA*QLA)*SS(I)/12\ NEXT I
2780 REM Bottom Stiffener
2790 W(3,1,1)=(-QD(3)-QDL-QDI+QLV)*SS(3)/12+WS(3)

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2800 W3121=(-QD(3)-QDL-QDI-QLP-QLA)*SS(3)/12-WS(3)
2810 W3122=(-QD(3)-QDL-QDI-QLR(3)-QLA)*SS(3)/12-WS(3)
2820 IF ABS(W3121)>ABS(W3122) THEN W(3,1,2)=W3121 ELSE W(3,1,2)=W3122
2830 REM Pinned-End: Wind or Seismic Forces
2840 REM Top Stiffener
2850 W(1,2,1)=0
2860 W(1,2,2)=(QD(1)+QDL+QDI-QLP+QW(1))*SS(1)/12+WS(1)
2870 REM Side Stiffeners
2880 FOR I=2 TO 4 STEP 2
2890 W1211=(QLV+QW(4))*SS(I)/12
2900 W1212=QLV*SS(I)/12+WES(I)
2910 IF W1211>W1212 THEN W(I,2,1)=W1211 ELSE W(I,2,1)=W1212
2920 W1221=(-QLP+QW(2)-CLA*QLA)*SS(I)/12
2930 W1222=(-QLP-CLA*QLA)*SS(I)/12+WES(I)
2940 IF ABS(W1221)>ABS(W1222) THEN W(I,2,2)=W1221 ELSE W(I,2,2)=W1222
2950 NEXT I
2960 REM Bottom Stiffener
2970 W(3,2,1)=0
2980 W3221=(-QD(3)-QDL-QDI-QLP-QLA+QW(3))*SS(3)/12-WS(3)
2990 W3222=(-QD(3)-QDL-QDI-QLR(3)-QLA+QW(3))*SS(3)/12-WS(3)
3000 IF ABS(W3221)>ABS(W3222) THEN W(3,2,2)=W3221 ELSE W(3,2,2)=W3222
3010 REM Pinned-End: Excursion Conditions
3020 REM Top Stiffener
3030 W(1,3,1)=(QD(1)+QDL+QDI+QLR(1)+QS+QXV)*SS(1)/12+WS(1)
3040 W(1,3,2)=(QD(1)+QDL+QDI-QXP)*SS(1)/12+WS(1)
3050 REM Side Stiffeners
3060 FOR I=2 TO 4 STEP 2
3070 W(I,3,1)=QXV*SS(I)/12\W(I,3,2)=(-QXP-CLA*QLA)*SS(I)/12\ NEXT I
3080 REM Bottom Stiffener
3090 W(3,3,1)=(-QD(3)-QDL-QDI+QXV)*SS(3)/12-WS(3)
3100 W(3,3,2)=(-QD(3)-QDL-QDI-QLA-QXP)*SS(3)/12-WS(3)
3110 IF CORR$='N' GOTO 3130
3120 FOR I=1 TO 3 STEP 2\T(I)=T(I)-CRA\ NEXT I
3130 RETURN
3140 REM PINNED-END STIFFENER AXIAL FORCE AND AXIAL STRESS SUBROUTINE
3150 IF CORR$='N' GOTO 3180
3160 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
3170 REM Axial Force due to Internal Vacuum or Pressure
3180 FOR I=1 TO 4
3190 ON I GOTO 3200,3240,3200,3240
3200 PVP(I,1,1)=QLV*SS(I)*(LFT(2)+LFT(4))/48
3210 PVP(I,2,1)=QXV*SS(I)*(LFT(2)+LFT(4))/48
3220 PVP(I,1,2)=-QLP*SS(I)*(LFT(2)+LFT(4))/48
3230 PVP(I,2,2)=-QXP*SS(I)*(LFT(2)+LFT(4))/48\ GOTO 3280
3240 PVP(I,1,1)=QLV*SS(I)*(LFT(1)+LFT(3))/48
3250 PVP(I,2,1)=QXV*SS(I)*(LFT(1)+LFT(3))/48
3260 PVP(I,1,2)=-QLP*SS(I)*(LFT(1)+LFT(3))/48
3270 PVP(I,2,2)=-QXP*SS(I)*(LFT(1)+LFT(3))/48
3280 NEXT I
3290 REM Axial Force due to Tension Field Action
3300 TERM1=(T(1)*LFT(1)+T(2)*LFT(2)+T(3)*LFT(3)+T(4)*LFT(4))*UWP/12
3310 TERM2=(QDI+QDL)*(LFT(1)+LFT(2)+LFT(3)+LFT(4))
3320 TERM3=(WS(1)*LFT(1)/SS(1)+WS(2)*LFT(2)/SS(2))*12
3330 TERM4=(WS(3)*LFT(3)/SS(3)+WS(4)*LFT(4)/SS(4))*12
3340 IF QLRD>QS THEN TERM5=QLRD*LFT(1) ELSE TERM5=QS*LFT(1)
3350 TERM6=QLAD*LFT(3)+WA(1)+WA(2)+WA(3)+WA(4)

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3360 WG=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6
3370 PS=(WG*(LSPAN-SS(2)/12)+WB)/4
3380 REM      Calculate Maximum Axial Stress
3390 REM      Top and bottom stiffeners
3400 FOR I=1 TO 3 STEP 2\ FOR J=1 TO 2\ FAM(I,J,1)=PVP(I,J,1)/(1000*AE(I))
3410      FAM(I,J,2)=PVP(I,J,2)/(1000*AE(I))\ NEXT J\ NEXT I
3420 REM      Side (vertical) stiffeners
3430 FOR I=2 TO 4 STEP 2\ FOR J=1 TO 2
3440      FAM(I,J,1)=(PVP(I,J,1)+PS)/(1000*AE(I))
3450      FAM(I,J,2)=PS/(1000*AE(I))\ NEXT J\ NEXT I
3460 REM      Calculate Axial Compressive Forces for Use in Computing Maximum
3470 REM      Deflections
3480 FOR I=1 TO 4\ FOR J=1 TO 2
3490      ON I GOTO 3500,3510,3500,3510
3500      P(I,J)=PVP(I,J,1)\ GOTO 3520
3510      P(I,J)=PVP(I,J,1)+PS
3520 NEXT J\ NEXT I
3530 IF CORR$='N' GOTO 3550
3540 FOR I=1 TO 4\ T(I)=T(I)-CRA\ NEXT I
3550 RETURN
3560 REM      MAXIMUM BENDING STRESS SUBROUTINE
3570 REM      Positive Loading
3580 FOR J=1 TO 3
3590      FBM(1,J,1)=.0015*W(J,1)*LFT(II)^2*(DST-Y1(II))/IE(II)
3600      FBM(2,J,1)=.0015*W(J,1)*LFT(II)^2*Y1(II)/IE(II)
3610      FBM(3,J,1)=.0015*W(J,1)*LFT(II)^2*(DST+T(II)-Y1(II))/IE(II)
3620 NEXT J
3630 REM      Negative Loading
3640 FOR J=1 TO 3
3650      FBM(1,J,2)=.0015*W(J,2)*LFT(II)^2*Y1(II)/IE(II)
3660      FBM(2,J,2)=.0015*W(J,2)*LFT(II)^2*(DST-Y1(II))/IE(II)
3670      FBM(3,J,2)=.0015*W(J,2)*LFT(II)^2*(DST+T(II)-Y1(II))/IE(II)
3680 NEXT J
3690 RETURN
3700 REM      ALLOWABLE AXIAL COMPRESSIVE STRESS SUBROUTINE
3710 CC=SQR(2*PI^2*ES/FYS)
3720 IF 12*LFT(II)/RE(II)>CC GOTO 3780
3730 IF SHP=3 THEN IF BF/TF>95/SQR(FYS) GOTO 3780 ELSE GOTO 3750
3740 IF BF/(2*TF)>95/SQR(FYS) GOTO 3780
3750 TERM1=(1-((12*LFT(II)/RE(II))^2)/(2*CC^2))*FYS
3760 TERM2=5/3+4.5*LFT(II)/(RE(II)*CC)-216*(LFT(II)/RE(II))^3/CC^3
3770 FA=TERM1/TERM2\ GOTO 3790
3780 FA=PI^2*ES/(276*(LFT(II)/RE(II))^2)
3790 RETURN
3800 REM      ALLOWABLE BENDING STRESS SUBROUTINE
3810 IF SHP=3 GOTO 4110
3820 REM      W and WT Shapes
3830 REM      Positive Loads
3840 IF WELDS(II)<>'C' GOTO 3980
3850 IF FAM(II,1,1)/FYS>.16 GOTO 3880
3860 IF DST/TW>(640/SQR(FYS))*(1-3.74*FAM(II,1,1)/FYS) GOTO 3980
3870 GOTO 3890
3880 IF DST/TW>257/SQR(FYS) GOTO 3980
3890 IF LBRC(II)>76/SQR(FYS) GOTO 3980
3900 IF LBRC(II)>20000*TF*BF/((DST+T(II))*FYS) GOTO 3980
3910 IF BF/(2*TF)>95/SQR(FYS) GOTO 3980

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3920 IF BF/(2*TF)>65/SQR(FYS) GOTO 3940
3930 FB(1,1)=.66*FYS\FB(2,1)=.66*FYS\FB(3,1)=.66*FYP\ GOTO 4080
3940 FB(1,1)=FYS*(.79-.002*BF*SQR(FYS)/(2*TF))
3950 FB(2,1)=FB(1,1)
3960 FB(3,1)=FB(1,1)*FYP/FYS
3970 GOTO 4080
3980 FB(1,1)=.6*FYS
3990 FB(3,1)=.6*FYP
4000 IF BF/(2*TF)>95/SQR(FYS) THEN FB(2,1)=0\ GOTO 4080
4010 IF LBRC(II)<=76*BF/SQR(FYS) THEN FB(2,1)=.6*FYS\ GOTO 4080
4020 IF LBRC(II)>SQR(510000/FYS)*RT GOTO 4050
4030 FB(2,1)=(2/3-FYS*(LBRC(II)/RT)^2/.153E+07)*FYS
4040 IF FB(2,1)>.6*FYS THEN FB(2,1)=.6*FYS\ GOTO 4080
4050 FB(2,1)=170000/(LBRC(II)/RT)^2
4060 IF FB(2,1)>.6*FYS THEN FB(2,1)=.6*FYS
4070 REM Negative Loads
4080 FB(1,2)=.6*FYS\FB(2,2)=.6*FYS\FB(3,2)=.6*FYP\ GOTO 4190
4090 REM Channels
4100 REM Positive Loads
4110 FB(1,1)=.6*FYS
4120 FB(3,1)=.6*FYP
4130 IF BF/TF>95/SQR(FYS) THEN FB(2,1)=0\ GOTO 4180
4140 IF LBRC(II)<=76*BF/SQR(FYS) THEN FB(2,1)=.6*FYS\ GOTO 4180
4150 FB(2,1)=12000*(BF*TF)/(LBRC(II)*(DST+T(II)))
4160 IF FB(2,1)>.6*FYS THEN FB(2,1)=.6*FYS
4170 REM Negative Loads
4180 FB(1,2)=.6*FYS\FB(2,2)=.6*FYS\FB(3,2)=.6*FYP
4190 RETURN
4200 REM INTERACTION FORMULAS SUBROUTINE
4210 FLAG=0
4220 REM Normal Operating Conditions, Excluding Wind and Seismic Forces
4230 REM Positive loading
4240 IF FAM(II,1,1)/FA>.15 GOTO 4270
4250 IF FAM(II,1,1)/FA+FBM(2,1,1)/FB(2,1)>1 GOTO 5140
4260 GOTO 4300
4270 TERM2=(1-276*AE(II)*FAM(II,1,1)*LFT(II)^2/(PI^2*ES*IE(II)))*FB(2,1)
4280 IF FAM(II,1,1)/FA+FBM(2,1,1)/TERM2>1 GOTO 5140
4290 REM Negative Loading
4300 ON II GOTO 4320,4360,4320,4360
4310 REM Top and bottom stiffeners
4320 IF ABS(FAM(II,1,2))/(.6*FYS)+ABS(FBM(1,1,2))/FB(1,2)>1 GOTO 5140
4330 IF ABS(FBM(2,1,2))/FB(2,2) GOTO 5140
4340 GOTO 4430
4350 REM Side (vertical) stiffeners
4360 IF FAM(II,1,2)/FA>.15 GOTO 4390
4370 IF FAM(II,1,2)/FA+ABS(FBM(2,1,2))/FB(2,2)>1 GOTO 5140
4380 GOTO 4430
4390 TERM2=(1-276*AE(II)*FAM(II,1,2)*LFT(II)^2/(PI^2*ES*IE(II)))*FB(2,2)
4400 IF FAM(II,1,2)/FA+ABS(FBM(2,1,2))/TERM2>1 GOTO 5140
4410 REM Normal Operating Conditions, Including Wind or Seismic Forces
4420 REM Positive loading
4430 IF .75*FAM(II,1,1)/FA>.15 GOTO 4460
4440 IF .75*FAM(II,1,1)/FA+.75*FBM(2,2,1)/FB(2,1)>1 GOTO 5140
4450 GOTO 4490
4460 TERM2=(1-207*AE(II)*FAM(II,1,1)*LFT(II)^2/(PI^2*ES*IE(II)))*FB(2,1)
4470 IF .75*FAM(II,1,1)/FA+.75*FBM(2,2,1)/TERM2>1 GOTO 5140

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4480 REM      Negative loading
4490 ON II GOTO 4510,4550,4510,4550
4500 REM      Top and bottom stiffeners
4510 IF ABS(FAM(II,1,2))/(.8*FYS)+.75*ABS(FBM(1,2,2))/FB(1,2)>1 GOTO 5140
4520 IF ABS(FBM(2,2,2))>(4/3)*FB(2,2) GOTO 5140
4530 GOTO 4620
4540 REM      Side (vertical) stiffeners
4550 IF .75*FAM(II,1,2)/FA>.15 GOTO 4580
4560 IF .75*FAM(II,1,2)/FA+.75*ABS(FBM(2,2,2))/FB(2,2)>1 GOTO 5140
4570 GOTO 4620
4580 TERM2=(1-207*AE(II)*FAM(II,1,2)*LFT(II)^2/(PI^2*ES*IE(II)))*FB(2,2)
4590 IF .75*FAM(II,1,2)/FA+.75*ABS(FBM(2,2,2))/TERM2>1 GOTO 5140
4600 REM      Excursion Conditions
4610 REM      Positive loading
4620 IF .6*FAM(II,2,1)/FA>.15 GOTO 4650
4630 IF .6*FAM(II,2,1)/FA+.6*FBM(2,3,1)/FB(2,1)>1 GOTO 5140
4640 GOTO 4700
4650 FB1=(5/3)*FB(2,1)
4660 IF FB1>FYS THEN FB1=FYS
4670 TERM2=(1-144*AE(II)*FAM(II,2,1)*LFT(II)^2/(PI^2*ES*IE(II)))*FB1
4680 IF .6*FAM(II,2,1)/FA+FBM(2,3,1)/TERM2>1 GOTO 5140
4690 REM      Negative loading
4700 ON II GOTO 4720,4760,4720,4760
4710 REM      Top and bottom stiffeners
4720 IF ABS(FAM(II,2,2))/FYS+ABS(FBM(1,3,2))/FYS>1 GOTO 5140
4730 IF ABS(FBM(2,3,2))>FYS GOTO 5140
4740 GOTO 4820
4750 REM      Side (vertical) stiffeners
4760 IF FAM(II,2,2)/FYS>.15 GOTO 4790
4770 IF FAM(II,2,2)/FYS+ABS(FBM(2,3,2))/FYS>1 GOTO 5140
4780 GOTO 4820
4790 TERM2=(1-144*AE(II)*FAM(II,2,2)*LFT(II)^2/(PI^2*ES*IE(II)))*FYS
4800 IF FAM(II,2,2)/FYS+ABS(FBM(2,3,2))/TERM2>1 GOTO 5140
4810 REM      CHECK MAXIMUM ADJACENT EFFECTIVE PLATE STRESS
4820 IF FYP>FYS GOTO 5150
4830 REM      Normal Operating Conditions, Excluding Wind and Seismic Forces
4840 REM      Positive loading
4850 IF FBM(3,1,1)>FB(3,1) OR FAM(II,1,1)>.6*FYP GOTO 5140
4860 REM      Negative loading
4870 ON II GOTO 4890,4920,4890,4920
4880 REM      Top and bottom stiffeners
4890 IF ABS(FBM(3,1,2))>FB(3,2) OR ABS(FAM(II,1,2))>.6*FYP GOTO 5140
4900 GOTO 4950
4910 REM      Side (vertical) stiffeners
4920 IF FAM(II,1,2)/(.6*FYP)+ABS(FBM(3,1,2))/FB(3,2)>1 GOTO 5140
4930 REM      Normal Operating Conditions, Including Wind or Seismic Forces
4940 REM      Positive loading
4950 IF FBM(3,2,1)>(4/3)*FB(3,1) OR FAM(II,1,1)>.8*FYP GOTO 5140
4960 REM      Negative loading
4970 ON II GOTO 4990,5020,4990,5020
4980 REM      Top and bottom stiffeners
4990 IF ABS(FBM(3,2,2))>(4/3)*FB(3,2) OR ABS(FAM(II,1,2))>.8*FYP GOTO 5140
5000 GOTO 5050
5010 REM      Side (vertical) stiffeners
5020 IF FAM(II,1,2)/(.8*FYP)+.75*ABS(FBM(3,2,2))/FB(3,2)>1 GOTO 5140
5030 REM      Excursion Conditions

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5040 REM      Positive loading
5050 IF FBM(3,3,1)>FYP OR FAM(II,2,1)>FYP GOTO 5140
5060 REM      Negative loading
5070 ON II GOTO 5090,5120,5080,5120
5080 REM      Top and bottom stiffeners
5090 IF ABS(FBM(3,3,2))>FYP OR ABS(FAM(II,2,2))>FYP GOTO 5140
5100 GOTO 5150
5110 REM      Side (vertical) stiffeners
5120 IF FAM(II,2,2)/FYP+ABS(FBM(3,3,2))/FYP>1 GOTO 5140
5130 GOTO 5150
5140 FLAG=1
5150 RETURN
5160 REM      COMBINED STIFFENER AND ADJACENT EFFECTIVE PLATE DEFLECTION SUBROUTINE
5170 FLAG=0
5180 REM      Calculate Maximum Allowable Stiffener Deflections
5190 FOR J=1 TO 3:DALLOW(J)=LFT(II)*12/DSA(J)\ NEXT J
5200 REM      Calculate Maximum Stiffener Deflections and Compare to Allowables
5210 REM      Simultaneous axial compression and transverse loading
5220 FOR J=1 TO 3
5230   ON J GOTO 5250,5250,5270
5240   REM      Normal operating conditions
5250   W=W(J,1)\P=P(II,1)\ GOTO 5280
5260   REM      Excursion conditions
5270   W=W(J,1)\P=P(II,2)
5280   K1=SQR(P/(1000*ES*IE(II)))
5290   DMAX=W*(1/COS(6*K1*LFT(II))-18*K1^2*LFT(II)^2-1)/(12*K1^2*PS)
5300   IF DMAX>DALLOW(J) GOTO 5390
5310 NEXT J
5320 IF II<>3 GOTO 5400
5330 REM      Transverse loading only (bottom stiffener)
5340 FOR J=1 TO 3
5350   DMAX=.0225*ABS(W(J,2))*LFT(II)^4/(ES*IE(II))
5360   IF DMAX>DALLOW(J) GOTO 5390
5370 NEXT J
5380 GOTO 5400
5390 FLAG=1
5400 RETURN
5410 REM      AISC 1.10.5.4 STIFFENER MOMENT OF INERTIA AND GROSS AREA REQUIREMENTS
5420 FLAG=0
5430 REM      Stiffener Moment of Inertia Requirement
5440 IW=IXS+AST*(DST-YS+T(II)/2)^2
5450 IF II=2 THEN LYT=LY(2)\LYB=LY(3)\ GOTO 5470
5460 LYT=LY(1)\LYB=LY(4)
5470 HWEB=12*LFT(II)-LYT-LYB
5480 IF IW<(HWEB/50)^4 GOTO 5610
5490 REM      Stiffener Gross Area Requirement
5500 ALPHA=SS(II)/HWEB
5510 K2=4+(5.34/ALPHA^2)
5520 CV=45000*K2/(FYP*(HWEB/T(II))^2)
5530 IF CV>.8 THEN CV=190*SQR(K2/FYP)/(HWEB/T(II))
5540 FVAVG=WG*LSPAN/(4000*HWEB*T(II))
5550 FVALL=FYP*CV/2.89
5560 IF FVALL>.4*FYP THEN FVALL=.4*FYP
5570 BETA=2.4*FVAVG/FVALL
5580 AREQ=(1-CV)*(ALPHA-ALPHA^2/SQR(1+ALPHA^2))*FYP*HWEB*T(II)*BETA/(2*FYS)
5590 IF AST<AREQ GOTO 5610

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5600 GOTO 5620

5610 FLAG=1

5620 RETURN

DUCT5.BAS

16:02

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SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT5
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO COMPUTE THE TRANSVERSE LOADS AND
40 REM   LOAD COMBINATIONS TO BE DESIGNED FOR IN THE RIGID FRAME DESIGN PROGRAM
50 REM
60 PROGRAM DUCT5(RECALC)
70 LET I3=3\I4=4\I12=12\I18=18\I36=36
80 DIM WES(I4),WS(I4),W1(I4,I18),W2(I4,I36),W3(I4,I12),QD(I4)
90 DIM T(I4),SS(I4),QW(I4),QLR(I3)
100 OPEN 'DATA3' FOR INPUT AS FILE #3\ OPEN 'DATA4' FOR INPUT AS FILE #4
110 OPEN 'DATA5' FOR INPUT AS FILE #5
120 INPUT #3,CLA,CORR$,CRA,LSPAN,EP,FYP,SEISZ
130 INPUT #3,UWP,QDL,QLA,QLP,QLV,QS,QXP,QXV
140 INPUT #3,LFT(1),LFT(2),LFT(3),LFT(4),QLR(1),QLR(3)
150 INPUT #3,T(1),T(2),T(3),T(4),QW(1),QW(2),QW(3),QW(4)
160 INPUT #4,HCOPY$,QDI,SHP,UWS,FYS,ES,QLRD,QLAD,WB
170 INPUT #5,SS(1),SS(2),SS(3),SS(4)
180 CLOSE #3,#4,#5
190 PRINT \ PRINT 'CALCULATING TRANSVERSE LOADS AND LOAD COMBINATIONS; PLEASE ' ;
200 PRINT 'WAIT'\ PRINT
210 IF RECALC=0 OR RECALC=2 THEN 240
220   OPEN 'DATA7' FOR INPUT AS FILE #7
230   INPUT #7,WS(1),WS(2),WS(3),WS(4)\ CLOSE #7
240 IF CORR$='N' GOTO 270
250   FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
260 REM   DETERMINE SEISMIC ZONE COEFFICIENT
270 IF SEISZ=0 THEN ZS=1/8\ GOTO 340
280 ON SEISZ GOTO 290,300,310,320
290   ZS=3/16\ GOTO 340
300   ZS=3/8\ GOTO 340
310   ZS=3/4\ GOTO 340
320   ZS=1
330 REM   DETERMINE STIFFENER SEISMIC LOADING
340 FOR I=2 TO 4 STEP 2\WES(I)=.45*ZS*((UWP*T(I)/12+QDL+QDI)*SS(I)/12+WS(I))
350 NEXT I\ IF CORR$='N' GOTO 380
360   FOR I=2 TO 4 STEP 2\T(I)=T(I)-CRA\ NEXT I
370 REM   CALCULATE RIGID FRAME STIFFENER TRANSVERSE LOADING CASES
380 FOR I=1 TO 3 STEP 2\QD(I)=UWP*T(I)/12\ NEXT I
390 REM   Normal Operation, Excluding Wind and Seismic Effects
400 W1(1,1)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS)*SS(1)/12+WS(1)
410 W1(2,1)=(QLV-CLA*QLA)*SS(2)/12\W1(4,1)=W1(2,1)
420 W1(3,1)=(-QD(3)-QDL-QDI+QLV-QLA)*SS(3)/12-WS(3)
430 W1(1,2)=(QD(1)+QDL+QDI+QLV)*SS(1)/12+WS(1)
440 W1(2,2)=(QLV-CLA*QLA)*SS(2)/12\W1(4,2)=W1(2,2)
450 W1(3,2)=(-QD(3)-QDL-QDI+QLV-QLA)*SS(3)/12-WS(3)
460 W1(1,3)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS)*SS(1)/12+WS(1)
470 W1(2,3)=QLV*SS(2)/12\W1(4,3)=W1(2,3)
480 W1(3,3)=(-QD(3)-QDL-QDI+QLV)*SS(3)/12-WS(3)
490 W1(1,4)=(QD(1)+QDL+QDI+QLV)*SS(1)/12+WS(1)
500 W1(2,4)=QLV*SS(2)/12\W1(4,4)=W1(2,4)
510 W1(3,4)=(-QD(3)-QDL-QDI+QLV)*SS(3)/12-WS(3)
520 W1(1,5)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS)*SS(1)/12+WS(1)
530 W1(2,5)=(-QLP-CLA*QLA)*SS(2)/12\W1(4,5)=W1(2,5)
540 W1(3,5)=(-QD(3)-QDL-QDI-QLP-QLA)*SS(3)/12-WS(3)
550 FOR I=1 TO 4\W1(I,6)=W1(I,5)\ NEXT I

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560 W1(1,7)=(QD(1)+QDL+QDI-QLP)*SS(1)/12+WS(1)
570 W1(2,7)=(-QLP-CLA*QLA)*SS(2)/12\W1(4,7)=W1(2,7)
580 W1(3,7)=(-QD(3)-QDL-QDI-QLP-QLA)*SS(3)/12-WS(3)
590 FOR I=1 TO 4\W1(I,8)=W1(I,7)\ NEXT I
600 W1(1,9)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS)*SS(1)/12+WS(1)
610 W1(2,9)=-QLP*SS(2)/12\W1(4,9)=W1(2,9)
620 W1(3,9)=(-QD(3)-QDL-QDI-QLP)*SS(3)/12-WS(3)
630 FOR I=1 TO 4\W1(I,10)=W1(I,9)\ NEXT I
640 W1(1,11)=(QD(1)+QDL+QDI-QLP)*SS(1)/12+WS(1)
650 W1(2,11)=-QLP*SS(2)/12\W1(4,11)=W1(2,11)
660 W1(3,11)=(-QD(3)-QDL-QDI-QLP)*SS(3)/12-WS(3)
670 FOR I=1 TO 4\W1(I,12)=W1(I,11)\ NEXT I
680 W1(1,13)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
690 W1(2,13)=-CLA*QLA*SS(2)/12\W1(4,13)=W1(2,13)
700 W1(3,13)=(-QD(3)-QDL-QDI-QLA-QLR(3))*SS(3)/12-WS(3)
710 W1(1,14)=(QD(1)+QDL+QDI)*SS(1)/12+WS(1)
720 W1(2,14)=-CLA*QLA*SS(2)/12\W1(4,14)=W1(2,14)
730 W1(3,14)=(-QD(3)-QDL-QDI-QLA-QLR(3))*SS(3)/12-WS(3)
740 W1(1,15)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
750 W1(2,15)=-CLA*QLA*SS(2)/12\W1(4,15)=W1(2,15)
760 W1(3,15)=(-QD(3)-QDL-QDI-QLA)*SS(3)/12-WS(3)
770 W1(1,16)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
780 W1(2,16)=0\W1(4,16)=0
790 W1(3,16)=(-QD(3)-QDL-QDI-QLR(3))*SS(3)/12-WS(3)
800 W1(1,17)=(QD(1)+QDL+QDI)*SS(1)/12+WS(1)
810 W1(2,17)=0\W1(4,17)=0
820 W1(3,17)=(-QD(3)-QDL-QDI-QLR(3))*SS(3)/12-WS(3)
830 W1(1,18)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
840 W1(2,18)=0\W1(4,18)=0
850 W1(3,18)=(-QD(3)-QDL-QDI)*SS(3)/12-WS(3)
860 REM Normal Operation, Including Wind or Seismic Effects
870 W2(1,1)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
880 W2(2,1)=(QLV-CLA*QLA+QW(2))*SS(2)/12
890 W2(3,1)=(-QD(3)-QDL-QDI+QLV-QLA+QW(3))*SS(3)/12-WS(3)
900 W2(4,1)=(QLV-CLA*QLA+QW(4))*SS(4)/12
910 W2(1,2)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS)*SS(1)/12+WS(1)
920 W2(2,2)=(QLV-CLA*QLA)*SS(2)/12-WES(2)
930 W2(3,2)=(-QD(3)-QDL-QDI+QLV-QLA)*SS(3)/12-WS(3)
940 W2(4,2)=(QLV-CLA*QLA)*SS(4)/12+WES(4)
950 W2(1,3)=(QD(1)+QDL+QDI+QLV+QW(1))*SS(1)/12+WS(1)
960 W2(2,3)=(QLV-CLA*QLA+QW(2))*SS(2)/12
970 W2(3,3)=(-QD(3)-QDL-QDI+QLV-QLA+QW(3))/12-WS(3)
980 W2(4,3)=(QLV-CLA*QLA+QW(4))*SS(4)/12
990 W2(1,4)=(QD(1)+QDL+QDI+QLV)*SS(1)/12+WS(1)
1000 W2(2,4)=(QLV-CLA*QLA)*SS(2)/12-WES(2)
1010 W2(3,4)=(-QD(3)-QDL-QDI+QLV-QLA)*SS(3)/12-WS(3)
1020 W2(4,4)=(QLV-CLA*QLA)*SS(4)/12+WES(4)
1030 W2(1,5)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1040 W2(2,5)=(QLV+QW(2))*SS(2)/12
1050 W2(3,5)=(-QD(3)-QDL-QDI+QLV+QW(3))*SS(3)/12-WS(3)
1060 W2(4,5)=(QLV+QW(4))*SS(4)/12
1070 W2(1,6)=(QD(1)+QDL+QDI+QLV+QLR(1)+QS)*SS(1)/12+WS(1)
1080 W2(2,6)=QLV*SS(2)/12-WES(2)
1090 W2(3,6)=(-QD(3)-QDL-QDI+QLV)*SS(3)/12-WS(3)
1100 W2(4,6)=QLV*SS(4)/12+WES(4)
1110 W2(1,7)=(QD(1)+QDL+QDI+QLV+QW(1))*SS(1)/12+WS(1)

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1120 W2(2,7)=(QLV+QW(2))*SS(2)/12
1130 W2(3,7)=(-QD(3)-QDL-QDI+QLV+QW(3))*SS(3)/12-WS(3)
1140 W2(4,7)=(QLV+QW(4))*SS(4)/12
1150 W2(1,8)=(QD(1)+QDL+QDI+QLV)*SS(1)/12+WS(1)
1160 W2(2,8)=QLV*SS(2)/12-WES(2)
1170 W2(3,8)=(-QD(3)-QDL-QDI+QLV)*SS(3)/12-WS(3)
1180 W2(4,8)=QLV*SS(4)/12+WES(4)
1190 W2(1,9)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1200 W2(2,9)=(-QLP-CLA*QLA+QW(2))*SS(2)/12
1210 W2(3,9)=(-QD(3)-QDL-QDI-QLP-QLA+QW(3))*SS(3)/12-WS(3)
1220 W2(4,9)=(-QLP-CLA*QLA+QW(4))*SS(4)/12
1230 FOR I=1 TO 4\W2(I,10)=W2(I,9)\ NEXT I
1240 W2(1,11)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS)*SS(1)/12+WS(1)
1250 W2(2,11)=(-QLP-CLA*QLA)*SS(2)/12-WES(2)
1260 W2(3,11)=(-QD(3)-QDL-QDI-QLP-QLA)*SS(3)/12-WS(3)
1270 W2(4,11)=(-QLP-CLA*QLA)*SS(4)/12+WES(4)
1280 FOR I=1 TO 4\W2(I,12)=W2(I,11)\ NEXT I
1290 W2(1,13)=(QD(1)+QDL+QDI-QLP+QW(1))*SS(1)/12+WS(1)
1300 W2(2,13)=(-QLP-CLA*QLA+QW(2))*SS(2)/12
1310 W2(3,13)=(-QD(3)-QDL-QDI-QLP-QLA+QW(3))*SS(3)/12-WS(3)
1320 W2(4,13)=(-QLP-CLA*QLA+QW(4))*SS(4)/12
1330 FOR I=1 TO 4\W2(I,14)=W2(I,13)\ NEXT I
1340 W2(1,15)=(QD(1)+QDL+QDI-QLP)*SS(1)/12+WS(1)
1350 W2(2,15)=(-QLP-CLA*QLA)*SS(2)/12-WES(2)
1360 W2(3,15)=(-QD(3)-QDL-QDI-QLP-QLA)*SS(3)/12-WS(3)
1370 W2(4,15)=(-QLP-CLA*QLA)*SS(4)/12+WES(4)
1380 FOR I=1 TO 4\W2(I,16)=W2(I,15)\ NEXT I
1390 W2(1,17)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1400 W2(2,17)=(-QLP+QW(2))*SS(2)/12
1410 W2(3,17)=(-QD(3)-QDL-QDI-QLP+QW(3))*SS(3)/12-WS(3)
1420 W2(4,17)=(-QLP+QW(4))*SS(4)/12
1430 FOR I=1 TO 4\W2(I,18)=W2(I,17)\ NEXT I
1440 W2(1,19)=(QD(1)+QDL+QDI-QLP+QLR(1)+QS)*SS(1)/12+WS(1)
1450 W2(2,19)=-QLP*SS(2)/12-WES(2)
1460 W2(3,19)=(-QD(3)-QDL-QDI-QLP)*SS(3)/12-WS(3)
1470 W2(4,19)=-QLP*SS(4)/12+WES(4)
1480 FOR I=1 TO 4\W2(I,20)=W2(I,19)\ NEXT I
1490 W2(1,21)=(QD(1)+QDL+QDI-QLP+QW(1))*SS(1)/12+WS(1)
1500 W2(2,21)=(-QLP+QW(2))*SS(2)/12
1510 W2(3,21)=(-QD(3)-QDL-QDI-QLP+QW(3))*SS(3)/12-WS(3)
1520 W2(4,21)=(-QLP+QW(4))*SS(4)/12
1530 FOR I=1 TO 4\W2(I,22)=W2(I,21)\ NEXT I
1540 W2(1,23)=(QD(1)+QDL+QDI-QLP)*SS(1)/12+WS(1)
1550 W2(2,23)=-QLP*SS(2)/12-WES(2)
1560 W2(3,23)=(-QD(3)-QDL-QDI-QLP)*SS(3)/12-WS(3)
1570 W2(4,23)=-QLP*SS(4)/12+WES(4)
1580 FOR I=1 TO 4\W2(I,24)=W2(I,23)\ NEXT I
1590 W2(1,25)=(QD(1)+QDL+QDI+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1600 W2(2,25)=(-CLA*QLA+QW(2))*SS(2)/12
1610 W2(3,25)=(-QD(3)-QDL-QDI-QLA-QLR(3)+QW(3))*SS(3)/12-WS(3)
1620 W2(4,25)=(-CLA*QLA+QW(4))*SS(4)/12
1630 W2(1,26)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
1640 W2(2,26)=-CLA*QLA*SS(2)/12-WES(2)
1650 W2(3,26)=(-QD(3)-QDL-QDI-QLA-QLR(3))*SS(3)/12-WS(3)
1660 W2(4,26)=-CLA*QLA*SS(4)/12+WES(4)
1670 W2(1,27)=(QD(1)+QDL+QDI+QW(1))*SS(1)/12+WS(1)

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1680 W2(2,27)=(-CLA*QLA+QW(2))*SS(2)/12
1690 W2(3,27)=(-QD(3)-QDL-QDI-QLA-QLR(3)+QW(3))*SS(3)/12-WS(3)
1700 W2(4,27)=(-CLA*QLA+QW(4))*SS(4)/12
1710 W2(1,28)=(QD(1)+QDL+QDI)*SS(1)/12+WS(1)
1720 W2(2,28)=-CLA*QLA*SS(2)/12-WES(2)
1730 W2(3,28)=(-QD(3)-QDL-QDI-QLA-QLR(3))*SS(3)/12-WS(3)
1740 W2(4,28)=-CLA*QLA*SS(4)/12+WES(4)
1750 W2(1,29)=(QD(1)+QDL+QDI+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1760 W2(2,29)=(-CLA*QLA+QW(2))*SS(2)/12
1770 W2(3,29)=(-QD(3)-QDL-QDI-QLA+QW(3))*SS(3)/12-WS(3)
1780 W2(4,29)=(-CLA*QLA+QW(4))*SS(4)/12
1790 W2(1,30)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
1800 W2(2,30)=-CLA*QLA*SS(2)/12-WES(2)
1810 W2(3,30)=(-QD(3)-QDL-QDI-QLA)*SS(3)/12-WS(3)
1820 W2(4,30)=-CLA*QLA*SS(4)/12+WES(4)
1830 W2(1,31)=(QD(1)+QDL+QDI+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
1840 W2(2,31)=QW(2)*SS(2)/12
1850 W2(3,31)=(-QD(3)-QDL-QDI-QLR(3)+QW(3))*SS(3)/12-WS(3)
1860 W2(4,31)=QW(4)*SS(4)/12
1870 W2(1,32)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
1880 W2(2,32)=-WES(2)
1890 W2(3,32)=(-QD(3)-QDL-QDI-QLR(3))*SS(3)/12-WS(3)
1900 W2(4,32)=WES(4)
1910 W2(1,33)=(QD(1)+QDL+QDI+QW(1))*SS(1)/12+WS(1)
1920 W2(2,33)=QW(2)*SS(2)/12
1930 W2(3,33)=(-QD(3)-QDL-QDI-QLR(3)+QW(3))*SS(3)/12-WS(3)
1940 W2(4,33)=QW(4)*SS(4)/12
1950 W2(1,34)=(QD(1)+QDL+QDI)*SS(1)/12+WS(1)
1960 W2(2,34)=-WES(2)
1970 W2(3,34)=(-QD(3)-QDL-QDI-QLR(3))*SS(3)/12-WS(3)
1980 W2(4,34)=WES(4)
1990 W2(1,35)=(QD(1)+QDL+QDI+QLR(1)+QS+QW(1))*SS(1)/12+WS(1)
2000 W2(2,35)=QW(2)*SS(2)/12
2010 W2(3,35)=(-QD(3)-QDL-QDI+QW(3))*SS(3)/12-WS(3)
2020 W2(4,35)=QW(4)*SS(4)/12
2030 W2(1,36)=(QD(1)+QDL+QDI+QLR(1)+QS)*SS(1)/12+WS(1)
2040 W2(2,36)=-WES(2)
2050 W2(3,36)=(-QD(3)-QDL-QDI)*SS(3)/12-WS(3)
2060 W2(4,36)=WES(4)
2070 REM      Excursion Conditions
2080 W3(1,1)=(QD(1)+QDL+QDI+QXV+QLR(1)+QS)*SS(1)/12+WS(1)
2090 W3(2,1)=(QXV-CLA*QLA)*SS(2)/12\W3(4,1)=W3(2,1)
2100 W3(3,1)=(-QD(3)-QDL-QDI+QXV-QLA)*SS(3)/12-WS(3)
2110 W3(1,2)=(QD(1)+QDL+QDI+QXV)*SS(1)/12+WS(1)
2120 W3(2,2)=(QXV-CLA*QLA)*SS(2)/12\W3(4,2)=W3(2,2)
2130 W3(3,2)=(-QD(3)-QDL-QDI+QXV-QLA)*SS(3)/12-WS(3)
2140 W3(1,3)=(QD(1)+QDL+QDI+QXV+QLR(1)+QS)*SS(1)/12+WS(1)
2150 W3(2,3)=QXV*SS(2)/12\W3(4,3)=W3(2,3)
2160 W3(3,3)=(-QD(3)-QDL-QDI+QXV)*SS(3)/12-WS(3)
2170 W3(1,4)=(QD(1)+QDL+QDI+QXV)*SS(1)/12+WS(1)
2180 W3(2,4)=QXV*SS(2)/12\W3(4,4)=W3(2,4)
2190 W3(3,4)=(-QD(3)-QDL-QDI+QXV)*SS(3)/12-WS(3)
2200 W3(1,5)=(QD(1)+QDL+QDI-QXP+QLR(1)+QS)*SS(1)/12+WS(1)
2210 W3(2,5)=(-QXP-CLA*QLA)*SS(2)/12\W3(4,5)=W3(2,5)
2220 W3(3,5)=(-QD(3)-QDL-QDI-QXP-QLA)*SS(3)/12-WS(3)
2230 FOR I=1 TO 4\W3(I,6)=W3(I,5)\ NEXT I

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DUCT5.BAS

16:04

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2240 W3(1,7)=(QD(1)+QDL+QDI-QXP)*SS(1)/12+WS(1)
2250 W3(2,7)=(-QXP-CLA*QLA)*SS(2)/12+W3(4,7)=W3(2,7)
2260 W3(3,7)=(-QD(3)-QDL-QDI+QXP-QLA)*SS(3)/12-WS(3)
2270 FOR I=1 TO 4\W3(I,8)=W3(I,7)\ NEXT I
2280 W3(1,9)=(QD(1)+QDL+QDI-QXP+QLR(1)+QS)*SS(1)/12+WS(1)
2290 W3(2,9)=-QXP*SS(2)/12+W3(4,9)=W3(2,9)
2300 W3(3,9)=(-QD(3)-QDL-QDI-QXP)*SS(3)/12-WS(3)
2310 FOR I=1 TO 4\W3(I,10)=W3(I,9)\ NEXT I
2320 W3(1,11)=(QD(1)+QDL+QDI-QXP)*SS(1)/12+WS(1)
2330 W3(2,11)=-QXP*SS(2)/12+W3(4,11)=W3(2,11)
2340 W3(3,11)=(-QD(3)-QDL-QDI-QXP)*SS(3)/12-WS(3)
2350 FOR I=1 TO 4\W3(I,12)=W3(I,11)\ NEXT I
2360 REM WRITE TRANSVERSE LOADS TO A FILE
2370 C$=', '\ OPEN 'DATA6' FOR OUTPUT AS FILE #6
2380 FOR I=1 TO 18\ PRINT #6,W1(1,I);C*;W1(2,I);C*;W1(3,I);C*;W1(4,I)\ NEXT I
2390 FOR I=1 TO 36\ PRINT #6,W2(1,I);C*;W2(2,I);C*;W2(3,I);C*;W2(4,I)\ NEXT I
2400 FOR I=1 TO 12\ PRINT #6,W3(1,I);C*;W3(2,I);C*;W3(3,I);C*;W3(4,I)\ NEXT I
2410 CLOSE #6\IO=0\ DIM WES(IO),WS(IO),W1(IO,IO),W2(IO,IO),W3(IO,IO),QD(IO)
2420 DIM T(IO),SS(IO),QW(IO),QLR(IO)
2430 IF RECALC=2 OR RECALC=3 THEN 2460
2440 PRINT 'CHAINING TO PROGRAM DUCT6; PLEASE WAIT'\ PRINT
2450 CHAIN 'DUCT6A' WITH RECALC
2460 PRINT 'CHAINING TO PROGRAM DUCT8; PLEASE WAIT'\ PRINT
2470 CHAIN 'DUCT8A' WITH RECALC
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DUCT6A.BAS

16:06

12-Mar-86

SET NO DOUBLE

10 REM PROGRAM NAME: DUCT6A

20 REM

30 REM THE PURPOSE OF THIS PROGRAM IS TO ENABLE PROGRAM DUCT5 TO CHAIN TO

40 REM PROGRAM DUCT6

50 REM

60 PROGRAM DUCT6A(RECALC)

70 CHAIN 'DUCT6' WITH RECALC

DUCT6.BAS

23:34

02-Apr-86

SET NO DOUBLE

! PROGRAM NAME: DUCT6

! THE PURPOSE OF THIS PROGRAM IS TO SELECT TRANSVERSE RIGID FRAME

! STIFFENERS

40 PROGRAM DUCT6(RECALC)

50 LET I2=2\I3=3\I4=4\I8=8\I12=12\I18=18\I36=36\ DIM SEC\$(I4),AST(I4),FA(I4)

60 DIM WS(I4),WELD\$(I4),LBRC(I4),FB(I4,I3,I2),FBM(I4,I3,I2),LY(I4),PLANGLE(I3)

70 DIM DST(I4),Y1(I4),IE(I4),RE(I4),BF(I4),TF(I4),TW(I4),RT(I4),AE(I4),IXS(I4)

80 DIM PVP(I4,I2,I2),FAM(I4,I2,I4),P(I4,I2,I4),DSA(I3),LFT(I4),T(I4),SS(I4)

90 DIM W1(I4,I18),W2(I4,I36),W3(I4,I12),M0(I4),A(I4,I4),B(I4,I8),D(I4),K1(I4)

100 DIM ANGDISP(I4),M(I4,I2),MMAXPOS(I4),MMAXNEG(I4),FAC(I4),FLAG(I4),PD(I4)

110 DIM QW(I4),QLR(I4),BE(I4),WA(I4),FLAG1(I4)

120 OPEN 'LP:' FOR OUTPUT AS FILE #1\ OPEN 'DATA3' FOR INPUT AS FILE #3

130 OPEN 'DATA4' FOR INPUT AS FILE #4\ OPEN 'DATA5' FOR INPUT AS FILE #5

140 INPUT #3,CLA,CORR\$,CRA,LSPAN,EP,FYP,SEISZ

150 INPUT #3,UWP,QDL,QLA,QLP,QLV,QS,QXP,QXV

160 INPUT #3,LFT(1),LFT(2),LFT(3),LFT(4),QLR(1),QLR(3)

170 INPUT #3,T(1),T(2),T(3),T(4),QW(1),QW(2),QW(3),QW(4)

180 INPUT #4,HCOPI\$,QDI,SHP,UWS,FYS,ES,QLRD,QLAD,WB

190 INPUT #4,LBRC(1),LBRC(2),LBRC(3),LBRC(4),WA(1),WA(2)

200 INPUT #4,WA(3),WA(4),DSA(1),DSA(2),DSA(3),LY(1),LY(2)

210 INPUT #4,LY(3),LY(4),WELD\$(1),WELD\$(2),WELD\$(3),WELD\$(4)

220 INPUT #5,SS(1),SS(2),SS(3),SS(4)\ CLOSE #3,#4,#5

230 OPEN 'DATA6' FOR INPUT AS FILE #6

240 FOR I=1 TO 18\ INPUT #6,W1(1,I),W1(2,I),W1(3,I),W1(4,I)\ NEXT I

250 FOR I=1 TO 36\ INPUT #6,W2(1,I),W2(2,I),W2(3,I),W2(4,I)\ NEXT I

260 FOR I=1 TO 12\ INPUT #6,W3(1,I),W3(2,I),W3(3,I),W3(4,I)\ NEXT I\ CLOSE #6

270 DEF FTAN(RAD)=SIN(RAD)/COS(RAD)

! Calculate stiffener axial forces due to internal vacuums and pressures

290 GOSUB 2770\ IF RECALC=1 THEN 2220

300 IF HCOPI\$='N' GOTO 320

310 PRINT CHR\$(27)+'[?4i'\ PRINT #1,CHR\$(12)\ PRINT CHR\$(27)+'[?5i'

320 AVAIL=0\ PRINT \ PRINT TAB(25);'RIGID FRAME STIFFENER DESIGN'\ PRINT \ PRINT

330 IF LFT(2)=LFT(4) THEN 500

340 PRINT TAB(30);'\*\*\* PLEASE NOTE \*\*\*'\ PRINT \ PRINT 'THE LENGTH OF SIDE 2 ';

350 PRINT 'IS DIFFERENT FROM THE LENGTH OF SIDE 4 FOR THIS DUCT CROSS'

360 PRINT 'SECTION. IN ORDER TO ENSURE THAT ADEQUATE RIGID FRAME STIFFENERS';

370 PRINT 'ARE SELECTED,'\ PRINT 'THIS SERIES OF PROGRAMS (STARTING WITH ';

380 PRINT 'PROGRAM DUCT1) SHOULD BE RUN TWICE. THE'\ PRINT 'FIRST RUN SHOULD';

390 PRINT 'DESIGNATE SIDE 2 AS THE LONGER SIDE AND SIDE 4 AS THE SHORTER'

400 PRINT 'SIDE. THE SECOND RUN SHOULD DESIGNATE SIDE 2 AS THE SHORTER SIDE ';

410 PRINT 'AND SIDE 4 AS'\ PRINT 'THE LONGER SIDE. SIDE 1 REMAINS THE TOP ';

420 PRINT 'AND SIDE 3 REMAINS THE BOTTOM FOR BOTH'\ PRINT 'RUNS. THE TWO RU';

430 PRINT 'NS SHOULD BE COMPARED STIFFENER BY STIFFENER, AND THE'\ PRINT 'HE';

440 PRINT 'AVIER STIFFENER SECTION IN EACH CASE SHOULD BE SELECTED WHEN RIGID';

450 PRINT 'FRAME'\ PRINT 'STIFFENERS ARE DESIGNATED. THIS PROCEDURE IS REQ';

460 PRINT 'UIRED SINCE THE RIGID FRAME'\ PRINT 'PROGRAM ALWAYS DESIGNATES ';

470 PRINT 'SIDE 4 AS THE WINDWARD SIDE OF THE DUCT. IT APPLIES'\ PRINT 'ON';

480 PRINT 'LY TO RIGID FRAME STIFFENER DESIGN. THIS PROCEDURE DOES NOT ';

490 PRINT 'APPLY TO PINNED-\ PRINT 'END STIFFENER DESIGN.'\ PRINT \ PRINT

500 PRINT 'ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS'

510 PRINT '(REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED ';

520 PRINT 'TO HAVE THE'\ PRINT 'SAME NOMINAL DEPTH')\ INPUT TRIALND\ PRINT

! Test to insure that chosen trial nominal depth is available

540 ON SHP GOTO 550,590,640

550 IF TRIALND=6 OR TRIALND=8 OR TRIALND=10 THEN AVAIL=1\ GOTO 670

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560 IF TRIALND=12 OR TRIALND=14 OR TRIALND=16 THEN AVAIL=1\ GOTO 670
570 IF TRIALND=18 OR TRIALND=21 OR TRIALND=24 THEN AVAIL=1\ GOTO 670
580 GOTO 670
590 IF TRIALND=3 OR TRIALND=4 OR TRIALND=5 THEN AVAIL=1\ GOTO 670
600 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 670
610 IF TRIALND=9 OR TRIALND=10.5 OR TRIALND=12 THEN AVAIL=1\ GOTO 670
620 IF TRIALND=13.5 OR TRIALND=15 OR TRIALND=16.5 THEN AVAIL=1\ GOTO 670
630 GOTO 670
640 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 670
650 IF TRIALND=9 OR TRIALND=10 OR TRIALND=12 THEN AVAIL=1\ GOTO 670
660 IF TRIALND=15 THEN AVAIL=1
670 IF AVAIL=1 GOTO 760
680 PRINT \ PRINT 'THE TRIAL NOMINAL DEPTH THAT YOU HAVE CHOSEN IS NOT ' ;
690 PRINT 'AVAILABLE IN THIS DESIGN\ PRINT 'PROGRAM FOR THE STIFFENER ' ;
700 PRINT 'SECTION SHAPE THAT YOU SELECTED PREVIOUSLY. IF YOU'
710 PRINT 'WISH TO CHANGE THE STIFFENER SECTION SHAPE (W SHAPE, WT OR ' ;
720 PRINT 'CHANNEL), YOU MUST\ PRINT 'INTERRUPT THIS PROGRAM (PRESS ' ;
730 PRINT 'Interrupt - Do KEYS), AND RELOAD AND RERUN PROGRAM'
740 PRINT 'DUCT3. OTHERWISE, PLEASE ENTER A DIFFERENT TRIAL NOMINAL ' ;
750 PRINT 'DEPTH.\ GOTO 300
760 IF HCOPIY$='N' THEN 770 ELSE PRINT CHR$(27)+'[?4i'
770 PRINT 'TRANSVERSE RIGID FRAME STIFFENERS ARE BEING SELECTED. THIS PROCE';
780 PRINT 'SS MAY TAKE\ PRINT 'FROM 30 SECONDS TO TWO HOURS. THE LOAD CON';
790 PRINT 'DITION, LOAD CASE AND STIFFENER\ PRINT 'SECTION PRINTOUTS TO THIS';
800 PRINT ' SCREEN (WHICH WILL COMMENCE MOMENTARILY) MAY BE DIS-';
810 PRINT 'REGARDED. THEY ARE PROVIDED SIMPLY TO GIVE YOU SOME IDEA OF THE ' ;
820 PRINT 'STIFFENER\ PRINT 'SELECTION PROGRESS, AND TO REASSURE YOU THAT ' ;
830 PRINT 'THIS PROGRAM IS NOT "LOST". THE\ PRINT 'FINAL STIFFENER SECTION';
840 PRINT ' SELECTION WILL BE PRINTED OUT ON THE LINE PRINTER (IF'
850 PRINT 'YOU REQUESTED A HARD COPY OF THE STIFFENER SELECTION OUTPUT). ' ;
860 PRINT 'PLEASE WAIT.\ PRINT
870 FOR I=1 TO 4\ SEC$(I)='*****'\ WS(I)=0\ FLAG1(I)=0\ NEXT I
880 MAXWT=0\ ON SHP GOTO 890,900,910
890 OPEN 'WSHAPE' FOR INPUT AS FILE #10\ GOTO 920
900 OPEN 'WT' FOR INPUT AS FILE #10\ GOTO 920
910 OPEN 'C' FOR INPUT AS FILE #10
920 IF MAXWT=1 THEN CLOSE #10\ GOTO 2340\ REM (End of File Check)
930 ON SHP GOTO 940,950,960\ REM (Read W, WT or Channel shape properties)
940 GOSUB 2890\ GOTO 970
950 GOSUB 2980\ GOTO 970
960 GOSUB 3050
970 IF NDST<>TRIALND GOTO 930
! Heaviest possible section for nominal depth check
990 IF MAXND=TRIALND THEN MAXWT=1
1000 FOR I=1 TO 4\ IF SEC$(I)<>'*****' THEN 1050
! Calculate effective section properties
1020 GOSUB 3120\ AST(I)=AST\ DST(I)=DST\ BF(I)=BF\ TF(I)=TF\ TW(I)=TW
1030 RT(I)=RT\ IXS(I)=IXS\ YS(I)=YS
1040 WS(I)=AST*UWS/144\ REM (Calculate trial stiffener weights)
1050 GOSUB 3190\ NEXT I\ REM (Calc. allow. stiff. axial compress. stresses)
1060 GOSUB 3290\ REM (Calculate stiffener axial load and stress combinations)
1070 FOR LCOND=1 TO 3
1080 ON LCOND GOTO 1090,1100,1110
1090 LCASE=18\ GOTO 1120
1100 LCASE=36\ GOTO 1120
1110 LCASE=12

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1120   DIM W(I4,LCASE)
1130   FOR LC=1 TO LCASE
!       Calculate stiffener fixed-end moments
1150       FOR I=1 TO 4\ ON LCOND GOTO 1160,1170,1180
1160           W(I,LC)=W1(I,LC)\ GOTO 1190
1170           W(I,LC)=W2(I,LC)\ GOTO 1190
1180           W(I,LC)=W3(I,LC)
1190       M0(I)=W(I,LC)*LFT(I)^2/1000\ NEXT I
1200       GOSUB 3550\ REM   (Calculate rigid frame stiffener end moments)
!       Calculate maximum positive and negative stiffener moments and
1220       GOSUB 4000\ REM   maximum stiffener and plate bending stresses
!       Match transverse load cases with appropriate axial load comb.
1240       ON LCOND GOTO 1250,1320,1420
1250           IF LC<>1 AND LC<>2 AND LC<>3 AND LC<>4 THEN 1270
1260               FOR I=1 TO 4\FAC(I)=FAM(I,1,1)\ NEXT I\ GOTO 1480
1270           IF LC<>5 AND LC<>7 AND LC<>9 AND LC<>11 THEN 1290
1280               FOR I=1 TO 4\FAC(I)=FAM(I,1,2)\ NEXT I\ GOTO 1480
1290           IF LC<>6 AND LC<>8 AND LC<>10 AND LC<>12 THEN 1310
1300               FOR I=1 TO 4\FAC(I)=FAM(I,1,3)\ NEXT I\ GOTO 1480
1310           FOR I=1 TO 4\FAC(I)=FAM(I,1,4)\ NEXT I\ GOTO 1480
1320           IF LC=1 OR LC=2 OR LC=3 OR LC=4 GOTO 1340
1330           IF LC<>5 AND LC<>6 AND LC<>7 AND LC<>8 THEN 1350
1340               FOR I=1 TO 4\FAC(I)=FAM(I,1,1)\ NEXT I\ GOTO 1480
1350           IF LC=9 OR LC=11 OR LC=13 OR LC=15 GOTO 1370
1360           IF LC<>17 AND LC<>19 AND LC<>21 AND LC<>23 THEN 1380
1370               FOR I=1 TO 4\FAC(I)=FAM(I,1,2)\ NEXT I\ GOTO 1480
1380           IF LC=10 OR LC=12 OR LC=14 OR LC=16 GOTO 1400
1390           IF LC<>18 AND LC<>20 AND LC<>22 AND LC<>24 THEN 1410
1400               FOR I=1 TO 4\FAC(I)=FAM(I,1,3)\ NEXT I\ GOTO 1480
1410           FOR I=1 TO 4\FAC(I)=FAM(I,1,4)\ NEXT I\ GOTO 1480
1420           IF LC<>1 AND LC<>2 AND LC<>3 AND LC<>4 THEN 1440
1430               FOR I=1 TO 4\FAC(I)=FAM(I,2,1)\ NEXT I\ GOTO 1480
1440           IF LC<>5 AND LC<>7 AND LC<>9 AND LC<>11 THEN 1460
1450               FOR I=1 TO 4\FAC(I)=FAM(I,2,2)\ NEXT I\ GOTO 1480
1460           FOR I=1 TO 4\FAC(I)=FAM(I,2,3)\ NEXT I
!       Calculate allowable stiffener and adj. plate bending stresses
1480       FOR I=1 TO 4\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1500
1490           GOSUB 4160
1500       NEXT I\ REM   Check interaction formulas
1510       FOR I=1 TO 4\ FLAG(I)=0\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1530
1520           GOSUB 4590
1530       NEXT I
1540       FLAG1=1\FLAG2=0\ FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'
1550           IF SEC$(I)='*****' THEN FLAG1=0
1560           IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1570       NEXT I\ IF FLAG1=1 AND FLAG2=1 THEN 1840
!       Check stiffener deflections
!       Calculate stiffener fixed-end moments (incl. axial forces)
1600       FOR I=1 TO 4\ PD(I)=FAC(I)*AE(I)*1000\ IF PD(I)<=0 THEN 1630
1610           K1(I)=SQR(PD(I)/(1000*ES*IE(I)))\ TERM1=6*K1(I)*LFT(I)
1620           M0(I)=W(I,LC)*(1-TERM1/FNTAN(TERM1))/12000*K1(I)^2\ GOTO 1640
1630           M0(I)=W(I,LC)*LFT(I)^2/1000
1640       NEXT I
1650       GOSUB 3550\ REM   Calc. stiffener end moments (incl. axial forces)
!       Calculate and check maximum stiffener and plate deflection
1670       FOR I=1 TO 4\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1690

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1680      GOSUB 5030
1690      NEXT I
1700      FLAG1=1\FLAG2=0\ FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'
1710          IF SEC$(I)='*****' THEN FLAG1=0
1720          IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1730      NEXT I\ IF FLAG1=1 AND FLAG2=1 THEN 1840
!          Check stiffener moment of inertia and gross area requirements
!          (vertical stiffeners only)
1760      FOR I=2 TO 4 STEP 2\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1780
1770          GOSUB 5230
1780      NEXT I
1790      FLAG1=1\FLAG2=0
1800      FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'
1810          IF SEC$(I)='*****' THEN FLAG1=0
1820          IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1830      NEXT I\ IF FLAG1=0 OR FLAG2=0 THEN 1850
1840      LC=LCASE\LCOND=3
1850      PRINT 'LOAD CASE';LC,SECT$;TAB(29);SEC$(1);TAB(42);SEC$(2);TAB(55);
1860      PRINT SEC$(3);TAB(68);SEC$(4)\ NEXT LC
1870      PRINT 'LOAD CONDITION';LCOND\ NEXT LCOND
1880      FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)<>'*****' GOTO 1900
1890      SEC$(I)=SECT$\ GOTO 1930
1900      IF SEC$(I)<>'FAILED' GOTO 1930
1910      IF RECALC=1 THEN FLAG3=1
1920      SEC$(I)='*****'\FLAG=1\ GOTO 1940
1930      FLAG1(I)=1
1940      NEXT I\ IF FLAG=1 GOTO 920
1950      CLOSE #10\ IF RECALC=1 AND FLAG3=0 THEN 2340
!          Ensure that side stiffeners are the same size if lengths are equal
1970      IF LFT(2)<>LFT(4) OR WS(2)=WS(4) THEN 2060
1980      IF WS(2)<WS(4) THEN 2020
1990      SEC$(4)=SEC$(2)\AST(4)=AST(2)\DST(4)=DST(2)\BF(4)=BF(2)\TF(4)=TF(2)
2000      TW(4)=TW(2)\RT(4)=RT(2)\IXS(4)=IXS(2)\WS(4)=WS(2)\AE(4)=AE(2)
2010      Y1(4)=Y1(2)\IE(4)=IE(2)\RE(4)=RE(2)\YS(4)=YS(2)\ GOTO 2060
2020      SEC$(2)=SEC$(4)\AST(2)=AST(4)\DST(2)=DST(4)\BF(2)=BF(4)\TF(2)=TF(4)
2030      TW(2)=TW(4)\RT(2)=RT(4)\IXS(2)=IXS(4)\WS(2)=WS(4)\AE(2)=AE(4)
2040      Y1(2)=Y1(4)\IE(2)=IE(4)\RE(2)=RE(4)\YS(2)=YS(4)
!          Recalculate transverse loads using actual stiffener weights
2060      OPEN 'DATA5' FOR OUTPUT AS FILE #5
2070      C$=', '\ PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #5
2080      OPEN 'DATA7' FOR OUTPUT AS FILE #7
2090      PRINT #7,WS(1);C$;WS(2);C$;WS(3);C$;WS(4)\ CLOSE #7
2100      OPEN 'DATA8' FOR OUTPUT AS FILE #8
2110      FOR I=1 TO 4\ PRINT #8,SEC$(I);C$;AST(I);C$;DST(I);C$;BF(I);C$;TF(I)
2120      PRINT #8,TW(I);C$;RT(I);C$;IXS(I);C$;AE(I);C$;IE(I);C$;RE(I);C$;Y1(I)
2130      PRINT #8,YS(I)\ NEXT I\ PRINT #8,TRIALND\ CLOSE #8\IO=0\ DIM FLAG1(10)
2140      DIM SEC$(10),AST(10),FA(10),WA(10),QA(10),QLR(10),BE(10),WS(10),Y1(10)
2150      DIM WELD$(10),LBRC(10),FB(10,10,10),FBM(10,10,10),LY(10),PLANGLE(10)
2160      DIM DST(10),IE(10),RE(10),BF(10),TF(10),TW(10),RT(10),AE(10),IXS(10)
2170      DIM W1(10,10),W2(10,10),W3(10,10),M0(10),A(10,10),B(10,10),D(10),K1(10)
2180      DIM ANGDISP(10),M(10,10),MMAXPOS(10),MMAXNEG(10),FAC(10),FLAG(10),PD(10)
2190      PRINT \ PRINT 'CHAINING TO DUCT5 TO RECALCULATE TRANSVERSE LOADS BASED ON'
2200      PRINT 'ACTUAL STIFFENER WEIGHTS; PLEASE WAIT'
2210      CLOSE #1\RECALC=1\ CHAIN 'DUCT5' WITH RECALC
2220      OPEN 'DATA7' FOR INPUT AS FILE #7\ OPEN 'DATA8' FOR INPUT AS FILE #8
2230      INPUT #7,WS(1),WS(2),WS(3),WS(4)\ CLOSE #7

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2240 FOR I=1 TO 4\ INPUT #8,SEC$(I),AST(I),DST(I),BF(I),TF(I)
2250 INPUT #8,TW(I),RT(I),IXS(I),AE(I),IE(I),RE(I),Y1(I)\ INPUT #8,YS(I)
2260 NEXT I\ INPUT #8,TRIALND\ CLOSE #8
2270 MAXWT=0\ ON SHP GOTO 2280,2290,2300
2280 OPEN 'WSHAPE' FOR INPUT AS FILE #10\ GOTO 2320
2290 OPEN 'WT' FOR INPUT AS FILE #10\ GOTO 2320
2300 OPEN 'C' FOR INPUT AS FILE #10
! Recalculate allowable stiffener axial compressive stresses
2320 FOR I=1 TO 4\ GOSUB 3190\FLAG1(I)=0\ NEXT I
2330 FLAG3=0\ GOTO 1060
2340 IF HCOPY$='Y' THEN PRINT CHR$(27)+'[?5i'
2350 PRINT \ PRINT TAB(38);'RIGID FRAME STIFFENERS'\ PRINT
2360 PRINT TAB(23);'SIDE 1';TAB(38);'SIDE 2';TAB(53);'SIDE 3';TAB(68);'SIDE 4'
2370 PRINT \ PRINT 'STIFFENER SPACING';TAB(25);SS(1);TAB(40);SS(2);TAB(55);
2380 PRINT SS(3);TAB(70);SS(4)\ PRINT ' (INCHES)'
2390 PRINT 'STIFFENER SECTION';TAB(21);
2400 FOR I=1 TO 4\ PRINT USING "CCCCCCCCCCC ",SEC$(I);\ NEXT I
2410 PRINT \ PRINT \ PRINT
2420 FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)='*****' THEN FLAG=1
2430 NEXT I\ IF FLAG=0 GOTO 2480
2440 PRINT 'NOTE: "*****" INDICATES THAT AN ADEQUATE RIGID FRAME STIFFENER ';
2450 PRINT 'SECTION WITH'\ PRINT TAB(6);TRIALND;'INCH NOMINAL DEPTH DOES NOT ';
2460 PRINT 'EXIST. YOU MUST SELECT STIFFENER'\ PRINT TAB(7);'SECTIONS WITH ';
2470 PRINT 'A GREATER NOMINAL DEPTH.'\ PRINT \ PRINT
2480 PRINT 'DO YOU WISH TO ';
2490 PRINT 'SELECT RIGID FRAME STIFFENERS WITH A DIFFERENT NOMINAL DEPTH?'
2500 PRINT '(ENTER Y OR N)\ INPUT DIFF$\ PRINT \ PRINT
2510 PRINT 'DO YOU WISH TO SELECT A DIFFERENT STIFFENER SPACING? (Y OR N)'
2520 PRINT '(REMINDER: STIFFENER SPACINGS ARE THE SAME FOR ALL FOUR SIDES)'
2530 INPUT DIFSTIFF$\ PRINT \ PRINT \ IF DIFSTIFF$='N' GOTO 2620
2540 PRINT 'NOTE: THIS PROGRAM DOES NOT RECHECK MAXIMUM PLATE STRESSES AND ';
2550 PRINT 'DEFLECTIONS'\ PRINT 'ASSOCIATED WITH THE CHANGED STIFFENER SPACI';
2560 PRINT 'NGS. THIS CHECK MAY BE ACCOMPLISHED'\ PRINT 'BY EITHER REFERRING';
2570 PRINT 'TO THE STRESS-DEFLECTION TABLES GENERATED IN PROGRAM DUCT2'
2580 PRINT '(UNDER OPTION 1), OR BY REEXECUTING PROGRAM DUCT2 WITH THE REVIS';
2590 PRINT 'ED STIFFENER'\ PRINT 'SPACINGS.'\ PRINT
2600 PRINT 'ENTER THE REVISED STIFFENER SPACING IN INCHES'\ INPUT SS(1)\ PRINT
2610 FOR I=2 TO 4\SS(I)=SS(1)\ NEXT I
2620 IF DIFF$='Y' OR DIFSTIFF$='Y' THEN RECALC=0\ GOTO 300
2630 PRINT 'DO YOU WISH TO EXECUTE THE PINNED-END STIFFENER DESIGN PROGRAM?';
2640 PRINT '(Y OR N)\ INPUT PINNED$\ PRINT
2650 C$=', '\ OPEN 'DATA5' FOR OUTPUT AS FILE #5
2660 PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #1,#5\IO=0\ DIM FLAG1(10)
2670 DIM SEC$(10),AST(10),FA(10),QW(10),QLR(10),BE(10),WA(10),WS(10),DST(10)
2680 DIM WELD$(10),LBRC(10),FB(10,10,10),FBM(10,10,10),LY(10),PLANGLE(10)
2690 DIM Y1(10),IE(10),RE(10),BF(10),TF(10),TW(10),RT(10),AE(10),IXS(10)
2700 DIM PVP(10,10,10),FAM(10,10,10),P(10,10,10),DSA(10),LFT(10),T(10),SS(10)
2710 DIM W1(10,10),W2(10,10),W3(10,10),M0(10),A(10,10),B(10,10),D(10),K1(10)
2720 DIM ANGDISP(10),M(10,10),MMAXPOS(10),MMAXNEG(10),FAC(10),FLAG(10),PD(10)
2730 PRINT CHR$(27)+'[?4i'\ IF PINNED$='Y' GOTO 2750
2740 PRINT 'CHAINING TO PROGRAM DUCT7; PLEASE WAIT'\ CHAIN 'DUCT7'
2750 PRINT 'CHAINING TO PROGRAM DUCT4; PLEASE WAIT'\ CHAIN 'DUCT4'
! AXIAL FORCE DUE TO INTERNAL VACUUM OR PRESSURE
2770 FOR I=1 TO 4
2780 ON I GOTO 2790,2830,2790,2830
2790 PVP(I,1,1)=QLV*SS(I)*(LFT(2)+LFT(4))/48

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2800 PVP(I,2,1)=QXV*SS(I)*(LFT(2)+LFT(4))/48
2810 PVP(I,1,2)=-QLP*SS(I)*(LFT(2)+LFT(4))/48
2820 PVP(I,2,2)=-QXP*SS(I)*(LFT(2)+LFT(4))/48 GOTO 2870
2830 PVP(I,1,1)=QLV*SS(I)*(LFT(1)+LFT(3))/48
2840 PVP(I,2,1)=QXV*SS(I)*(LFT(1)+LFT(3))/48
2850 PVP(I,1,2)=-QLP*SS(I)*(LFT(1)+LFT(3))/48
2860 PVP(I,2,2)=-QXP*SS(I)*(LFT(1)+LFT(3))/48
2870 NEXT I\ RETURN
! W SHAPE PROPERTY RETRIEVAL SUBROUTINE
2890 LINPUT #10,WSHAPE1$\ LINPUT #10,WSHAPE2$
2900 LINPUT #10,WSHAPE3$\ LINPUT #10,WSHAPE4$
2910 SECT$=MID$(WSHAPE1$,1%,7%)\AST=VAL(MID$(WSHAPE1$,15%,6%))
2920 DST=VAL(MID$(WSHAPE1$,29%,5%))\NDST=VAL(MID$(WSHAPE1$,42%,2%))
2930 MAXND=VAL(MID$(WSHAPE1$,53%,2%))\TW=VAL(MID$(WSHAPE1$,56%,4%))
2940 BF=VAL(MID$(WSHAPE1$,68%,5%))\TF=VAL(MID$(WSHAPE2$,6%,5%))
2950 RT=VAL(MID$(WSHAPE2$,45%,4%))\IXS=VAL(MID$(WSHAPE2$,54%,7%))
2960 YS=DST/2\ RETURN
! WT PROPERTY RETRIEVAL SUBROUTINE
2980 LINPUT #10,WT1$\ LINPUT #10,WT2$\ LINPUT #10,WT3$\SECT$=MID$(WT1$,1%,12%)
2990 AST=VAL(MID$(WT1$,18%,5%))\DST=VAL(MID$(WT1$,31%,5%))
3000 NDST=VAL(MID$(WT1$,44%,4%))\MAXND=VAL(MID$(WT1$,53%,4%))
3010 TW=VAL(MID$(WT1$,58%,4%))\BF=VAL(MID$(WT1$,70%,5%))
3020 TF=VAL(MID$(WT2$,6%,5%))\RT=VAL(MID$(WT2$,45%,4%))
3030 IXS=VAL(MID$(WT2$,56%,6%))\YS=VAL(MID$(WT3$,19%,5%))\ RETURN
! CHANNEL PROPERTY RETRIEVAL SUBROUTINE
3050 LINPUT #10,C1$\ LINPUT #10,C2$\ LINPUT #10,C3$
3060 SECT$=MID$(C1$,1%,8%)\AST=VAL(MID$(C1$,18%,5%))
3070 DST=VAL(MID$(C1$,31%,5%))\NDST=VAL(MID$(C1$,31%,2%))
3080 MAXND=VAL(MID$(C1$,41%,2%))\TW=VAL(MID$(C1$,46%,4%))
3090 BF=VAL(MID$(C1$,58%,5%))\TF=VAL(MID$(C1$,72%,4%))
3100 IXS=VAL(MID$(C2$,56%,6%))\YS=DST/2\ RETURN
! STIFFENER EFFECTIVE SECTION PROPERTIES SUBROUTINE
3120 BE(I)=1.5*T(I)*SQR(EP/FYP)\ REM Effective Plate Width
3130 AE(I)=AST+BE(I)*T(I)\ REM Combined Stiffener and Eff. Plate Area
3140 Y1(I)=(AST*YS+BE(I)*T(I)*(DST+T(I)/2))/AE(I)\ REM Eff. Centroid. Axis
! Effective Moment of Inertia
3160 IE(I)=IXS+AST*(Y1(I)-YS)^2+BE(I)*T(I)*(T(I)^2/12+(DST+T(I)/2-Y1(I))^2)
3170 RE(I)=SQR(IE(I)/AE(I))\ RETURN \ REM Effective Radius of Gyration
! ALLOWABLE AXIAL COMPRESSIVE STRESS SUBROUTINE
3190 CC=SQR(2*PI^2*ES/FYS)
3200 IF 14.4*LFT(I)/RE(I)>CC GOTO 3260
3210 IF SHP=3 THEN IF BF(I)/TF(I)>95/SQR(FYS) THEN 3260 ELSE 3230
3220 IF BF(I)/(2*TF(I))>95/SQR(FYS) GOTO 3260
3230 TERM1=(1-((14.4*LFT(I)/RE(I))^2)/(2*CC^2))*FYS
3240 TERM2=5/3+5.4*LFT(I)/(RE(I)*CC)-373.25*(LFT(I)/RE(I))^3/CC^3
3250 FA(I)=TERM1/TERM2\ GOTO 3270
3260 FA(I)=PI^2*ES/(397.44*(LFT(I)/RE(I))^2)
3270 RETURN
! RIGID FRAME STIFFENER AXIAL FORCE AND AXIAL STRESS SUBROUTINE
3290 IF CORR$='N' THEN 3320
3300 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
! Axial Force due to Tension Field Action
3320 TERM1=(T(1)*LFT(1)+T(2)*LFT(2)+T(3)*LFT(3)+T(4)*LFT(4))*UWP/12
3330 TERM2=(QDI+QDL)*(LFT(1)+LFT(2)+LFT(3)+LFT(4))
3340 TERM3=(WS(1)*LFT(1)/SS(1)+WS(2)*LFT(2)/SS(2))*12
3350 TERM4=(WS(3)*LFT(3)/SS(3)+WS(4)*LFT(4)/SS(4))*12

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3360 IF QLRD>QS THEN TERM5=QLRD*LFT(1) ELSE TERM5=QS*LFT(1)
3370 TERM6=QLAD*LFT(3)+WA(1)+WA(2)+WA(3)+WA(4)
3380 WG=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6\PS=(WG*(LSPAN-SS(2)/12)+WB)/4
! Calculate Axial Load Combinations
3400 FOR J=1 TO 2\P(1,J,1)=PVP(1,J,1)\P(2,J,1)=PVP(2,J,1)+PS
3410 P(3,J,1)=PVP(3,J,1)\P(4,J,1)=PVP(4,J,1)+PS
3420 P(1,J,2)=PVP(1,J,2)\P(2,J,2)=PVP(2,J,2)
3430 P(3,J,2)=PVP(3,J,2)\P(4,J,2)=PVP(4,J,2)
3440 P(1,J,3)=PVP(1,J,2)\P(2,J,3)=PS
3450 P(3,J,3)=PVP(3,J,2)\P(4,J,3)=PS
3460 P(1,J,4)=0\P(2,J,4)=PS\P(3,J,4)=0\P(4,J,4)=PS\ NEXT J
! Calculate Axial Stress Combinations
3480 FOR I=1 TO 4\ FOR J=1 TO 2\ FOR K=1 TO 4
3490 FAM(I,J,K)=P(I,J,K)/(AE(I)*1000)\ NEXT K\ NEXT J\ NEXT I
3500 IF CORR$='N' GOTO 3520
3510 FOR I=1 TO 4\T(I)=T(I)-CRA\ NEXT I
3520 RETURN
! RIGID FRAME STIFFENER END MOMENT SUBROUTINE
! Fill Matrix A, the coefficient matrix
3550 A(1,1)=2*(IE(4)/LFT(4)+IE(1)/LFT(1))\A(1,2)=IE(1)/LFT(1)\A(1,3)=0
3560 A(1,4)=IE(4)/LFT(4)\A(2,1)=IE(1)/LFT(1)
3570 A(2,2)=2*(IE(1)/LFT(1)+IE(2)/LFT(2))\A(2,3)=IE(2)/LFT(2)\A(2,4)=0
3580 A(3,1)=0\A(3,2)=IE(2)/LFT(2)\A(3,3)=2*(IE(2)/LFT(2)+IE(3)/LFT(3))
3590 A(3,4)=IE(3)/LFT(3)\A(4,1)=IE(4)/LFT(4)\A(4,2)=0
3600 A(4,3)=IE(3)/LFT(3)\A(4,4)=2*(IE(3)/LFT(3)+IE(4)/LFT(4))
! Fill Vector D, the constant vector
3620 D(1)=6*(M0(1)-M0(4))/ES\D(2)=6*(M0(2)-M0(1))/ES
3630 D(3)=6*(M0(3)-M0(2))/ES\D(4)=6*(M0(4)-M0(3))/ES
3640 GOSUB 3790\ REM Go to inversion subroutine to find "A" Inverse
3650 FOR I=1 TO 4\ANGDISP(I)=0\ REM Mult. A' X D to get corner ang. displace.
3660 FOR K=1 TO 4\ANGDISP(I)=ANGDISP(I)+B(I,K)*D(K)\ NEXT K\ NEXT I
! Plug into slope-deflection equations to get stiffener end moments
3680 M(1,1)=-M0(1)+ES*IE(1)*(2*ANGDISP(1)+ANGDISP(2))/(6*LFT(1))
3690 M(1,2)=M0(1)+ES*IE(1)*(2*ANGDISP(2)+ANGDISP(1))/(6*LFT(1))
3700 M(2,1)=-M0(2)+ES*IE(2)*(2*ANGDISP(2)+ANGDISP(3))/(6*LFT(2))
3710 M(2,2)=M0(2)+ES*IE(2)*(2*ANGDISP(3)+ANGDISP(2))/(6*LFT(2))
3720 M(3,1)=-M0(3)+ES*IE(3)*(2*ANGDISP(3)+ANGDISP(4))/(6*LFT(3))
3730 M(3,2)=M0(3)+ES*IE(3)*(2*ANGDISP(4)+ANGDISP(3))/(6*LFT(3))
3740 M(4,1)=-M0(4)+ES*IE(4)*(2*ANGDISP(4)+ANGDISP(1))/(6*LFT(4))
3750 M(4,2)=M0(4)+ES*IE(4)*(2*ANGDISP(1)+ANGDISP(4))/(6*LFT(4))\ RETURN
! MATRIX INVERSION SUBROUTINE
! Gauss-Jordan Elimination (Matrix A is input, Matrix B is output)
! First, create Matrix B, with A on the left and I on the right
3790 FOR I=1 TO 4\ FOR J=1 TO 4\B(I,J+4)=0\B(I,J)=A(I,J)\ NEXT J
3800 B(I,I+4)=1\ NEXT I
! Perform row oriented operations to convert the left hand side of B
! to the identity matrix. The inverse of A will then be on the right.
3830 FOR K=1 TO 4
3840 IF K=4 THEN 3890 ELSE M%=K
! Find maximum element
3860 FOR I=K+1 TO 4\ IF ABS(B(I,K))>ABS(B(M%,K)) THEN M%=I
3870 NEXT I\ IF M%=K GOTO 3890
3880 FOR J=K TO 8/B=B(K,J)\B(K,J)=B(M%,J)\B(M%,J)=B\ NEXT J
3890 FOR J=K+1 TO 8\B(K,J)=B(K,J)/B(K,K)\ NEXT J\ REM Divide Row K
3900 IF K=1 GOTO 3930
3910 FOR I=1 TO K-1\ FOR J=K+1 TO 8\B(I,J)=B(I,J)-B(I,K)*B(K,J)\ NEXT J

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3920 NEXT I\ IF K=4 GOTO 3950
3930 FOR I=K+1 TO 4\ FOR J=K+1 TO 8\B(I,J)=B(I,J)-B(I,K)*B(K,J)\ NEXT J
3940 NEXT I
3950 NEXT K
! Retrieve inverse from the right side of Matrix B
3970 FOR I=1 TO 4\ FOR J=1 TO 4\B(I,J)=B(I,J+4)\ NEXT J\ NEXT I\ RETURN
! MAXIMUM STIFFENER MOMENT AND BENDING STRESS SUBROUTINE
! Calculate maximum positive and negative stiffener moments
4000 FOR I=1 TO 4\ IF M(I,1)<0 THEN MMAXNEG(I)=M(I,1) ELSE MMAXNEG(I)=0
4010 IF M(I,1)>0 THEN MMAXPOS(I)=M(I,1) ELSE MMAXPOS(I)=0
4020 FOR X=.5 TO LFT(I) STEP .5
4030 MX1=M(I,1)+(3*W(I,LC)*LFT(I)/500-(M(I,1)+M(I,2))/LFT(I))*X
4040 MX=MX1-3*W(I,LC)*X^2/500
4050 IF MX<MMAXNEG(I) THEN MMAXNEG(I)=MX
4060 IF MX>MMAXPOS(I) THEN MMAXPOS(I)=MX
4070 NEXT X\ NEXT I
! Calculate maximum bending stresses
4090 FOR I=1 TO 4\FBM(I,1,1)=MMAXPOS(I)*(DST(I)-Y1(I))/IE(I)
4100 FBM(I,2,1)=MMAXPOS(I)*Y1(I)/IE(I)
4110 FBM(I,3,1)=MMAXPOS(I)*(DST(I)+T(I)-Y1(I))/IE(I)
4120 FBM(I,1,2)=MMAXNEG(I)*Y1(I)/IE(I)
4130 FBM(I,2,2)=MMAXNEG(I)*(DST(I)-Y1(I))/IE(I)
4140 FBM(I,3,2)=MMAXNEG(I)*(DST(I)+T(I)-Y1(I))/IE(I)\ NEXT I\ RETURN
! ALLOWABLE BENDING STRESS SUBROUTINE
4160 IF LBRC(I)/12<LFT(I) THEN 4230
4170 IF ABS(MMAXNEG(I))>ABS(M(I,1)) AND ABS(MMAXNEG(I))>ABS(M(I,2)) THEN 4230
4180 IF MMAXPOS(I)>ABS(M(I,1)) AND MMAXPOS(I)>ABS(M(I,2)) THEN 4230
4190 IF ABS(M(I,1))<ABS(M(I,2)) THEN MRATIO=M(I,1)/M(I,2)\ GOTO 4210
4200 MRATIO=M(I,2)/M(I,1)
4210 CB=1.75+1.05*MRATIO+.3*MRATIO^2\ IF CB>2.3 THEN CB=2.3
4220 GOTO 4240
4230 CB=1
4240 IF SHP=3 GOTO 4500
! W and WT Shapes - Positive moments
4260 IF WELD*(I)<>'C' GOTO 4370
4270 IF FAC(I)/FYS>.16 GOTO 4290
4280 IF DST(I)/TW(I)>(640/SQR(FYS))*(1-3.74*FAC(I)/FYS) THEN 4370 ELSE 4300
4290 IF DST(I)/TW(I)>257/SQR(FYS) THEN 4370
4300 IF LBRC(I)>76/SQR(FYS) GOTO 4370
4310 IF LBRC(I)>20000*TF(I)*BF(I)/((DST(I)+T(I))*FYS) GOTO 4370
4320 IF BF(I)/(2*TF(I))>95/SQR(FYS) GOTO 4370
4330 IF BF(I)/(2*TF(I))>65/SQR(FYS) GOTO 4350
4340 FB(I,1,1)=.66*FYS\FB(I,2,1)=.66*FYS\FB(I,3,1)=.66*FYP\ GOTO 4460
4350 FB(I,1,1)=FYS*(.79-.002*BF(I)*SQR(FYS)/(2*TF(I)))\FB(I,2,1)=FB(I,1,1)
4360 FB(I,3,1)=FB(I,1,1)*FYP/FYS\ GOTO 4460
4370 FB(I,1,1)=.6*FYS\FB(I,3,1)=.6*FYP
4380 IF BF(I)/(2*TF(I))>95/SQR(FYS) THEN FB(I,2,1)=.001\ GOTO 4460
4390 IF LBRC(I)<76*BF(I)/SQR(FYS) THEN FB(I,2,1)=.6*FYS\ GOTO 4460
4400 IF LBRC(I)>SQR(510000*CB/FYS)*RT(I) GOTO 4430
4410 FB(I,2,1)=(2/3-FYS*(LBRC(I)/RT(I))^2/((.153E+07*CB))*FYS
4420 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS\ GOTO 4460
4430 FB(I,2,1)=170000*CB/(LBRC(I)/RT(I))^2
4440 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS
! W and WT Shapes - Negative moments
4460 FB(I,1,2)=.6*FYS\FB(I,2,2)=.6*FYS\FB(I,3,2)=.6*FYP\ GOTO 4570
! Channels - Positive moments

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4500 FB(I,1,1)=.6*FYS\FB(I,3,1)=.6*FYP
4510 IF BF(I)/TF(I)>95/SQR(FYS) THEN FB(I,2,1)=.001\ GOTO 4560
4520 IF LBRC(I)<=76*BF(I)/SQR(FYS) THEN FB(I,2,1)=.6*FYS\ GOTO 4560
4530 FB(I,2,1)=12000*CB*(BF(I)*TF(I))/(LBRC(I)*(DST(I)+T(I)))
4540 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS
! Channels - Negative moments
4560 FB(I,1,2)=.6*FYS\FB(I,2,2)=.6*FYS\FB(I,3,2)=.6*FYP
4570 RETURN
! INTERACTION FORMULAS SUBROUTINE
4590 FE=PI^2*ES*IE(I)/(397.44*LFT(I)^2*AE(I))
4600 ON LCOND GOTO 4610,4640,4670
4610 FA=FA(I)\FBSCP=FB(I,2,1)\FBSCN=FB(I,2,2)\CFYS=.6*FYS\CFYP=.6*FYP
4620 FBSTP=FB(I,1,1)\FBSTN=FB(I,1,2)\FBPP=FB(I,3,1)\FBPN=FB(I,3,2)
4630 GOTO 4710
4640 FA=4*FA(I)/3\FBSCP=4*FB(I,2,1)/3\FBSCN=4*FB(I,2,2)/3\CFYS=.8*FYS
4650 FE=4*FE/3\CFYP=.8*FYP\FBSTP=4*FB(I,1,1)/3\FBSTN=4*FB(I,1,2)/3
4660 FBPP=4*FB(I,3,1)/3\FBPN=4*FB(I,3,2)/3\ GOTO 4710
4670 FA=5*FA(I)/3\FBSCP=5*FB(I,2,1)/3\ IF FBSCP>FYS THEN FBSCP=FYS
4680 CFYS=FYS\FBSCN=5*FB(I,2,2)/3\ IF FBSCN>FYS THEN FBSCN=FYS
4690 FE=23*FE/12\CFYP=FYP\FBSTP=5*FB(I,1,1)/3\ IF FBSTP>FYS THEN FBSTP=FYS
4700 FBPP=FYP\FBPN=FYP\FBSTN=5*FB(I,1,2)/3\ IF FBSTN>FYS THEN FBSTN=FYS
4710 IF FAC(I)<=0 GOTO 4920
! Simultaneous Axial Compression and Transverse Loading
4730 IF FAC(I)/FA>.15 GOTO 4780
! Negligible Axial Stress
4750 IF FAC(I)/FA+FBM(I,2,1)/FBSCP>1 THEN 4990
4760 IF FAC(I)/FA+ABS(FBM(I,2,2))/FBSCN>1 THEN 4990 ELSE 4880
! Significant Axial Stress
4780 IF FAC(I)/FA+.85*FBM(I,2,1)/((1-FAC(I)/FE)*FBSCP)>1 GOTO 4990
4790 IF FAC(I)/FA+.85*ABS(FBM(I,2,2))/((1-FAC(I)/FE)*FBSCN)>1 GOTO 4990
4800 IF M(I,1)<0 GOTO 4820
4810 IF FAC(I)/CFYS+M(I,1)*Y1(I)/(IE(I)*FBSCP)>1 THEN 4990 ELSE 4830
4820 IF FAC(I)/CFYS-M(I,1)*(DST(I)-Y1(I))/(IE(I)*FBSCN)>1 GOTO 4990
4830 IF M(I,2)<0 GOTO 4860
4840 IF FAC(I)/CFYS+M(I,2)*(DST(I)-Y1(I))/(IE(I)*FBSCN)>1 THEN 4990
4850 GOTO 4880
4860 IF FAC(I)/CFYS-M(I,2)*Y1(I)/(IE(I)*FBSCP)>1 GOTO 4990
! Check Maximum Plate Stress
4880 IF FYP>=FYS GOTO 5000
4890 IF FAC(I)/CFYP+ABS(FBM(I,3,2))/FBPN>1 GOTO 4990
4900 IF FBM(I,3,1)>FBPP THEN 4990 ELSE 5000
! Simultaneous Axial Tension and Transverse Loading
4920 IF FAC(I)/CFYS+FBM(I,1,1)/FBSTP>1 GOTO 4990
4930 IF FAC(I)/CFYS+ABS(FBM(I,1,2))/FBSTN>1 GOTO 4990
4940 IF FBM(I,2,1)>FBSCP GOTO 4990
4950 IF ABS(FBM(I,2,2))>FBSCN GOTO 4990
! Check Maximum Plate Stress
4970 IF ABS(FAC(I))/CFYP+FBM(I,3,1)/FBPP>1 GOTO 4990
4980 IF ABS(FBM(I,3,2))>FBPN THEN 4990 ELSE 5000
4990 FLAG(I)=1
5000 RETURN
! COMBINED STIFFENER AND ADJACENT EFFECTIVE PLATE DEFLECTION SUBROUTINE
! Calculate Maximum Stiffener Deflection
5030 DMAX=0\ IF PD(I)<=0 GOTO 5130
! Simultaneous axial compression and transverse loading
5050 FOR X=.5 TO LFT(I) STEP .5\T1=12*K1(I)*X\T2=12*K1(I)*LFT(I)

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DUCT6.BAS

15:15

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5060 TERM1=FNTAN(6*K1(I)*LFT(I))*SIN(T1)+72*K1(I)^2*X^2+COS(T1)-1
5070 DSXA=W(I,LC)*TERM1/(12*K1(I)^2*PD(I))-6*W(I,LC)*LFT(I)*X/PD(I)
5080 DSXB1=-1000*M(I,1)*(SIN(T1)/FNTAN(T2)-COS(T1)-X/LFT(I)+1)/PD(I)
5090 DSXB2=-1000*M(I,2)*(SIN(T1)/SIN(T2)-X/LFT(I))/PD(I)
5100 DSX=DSXA+DSXB1+DSXB2\ IF ABS(DSX)>DMAX THEN DMAX=ABS(DSX)
5110 NEXT X\ GOTO 5190
! Simultaneous axial tension and transverse loading
5130 FOR X=.5 TO LFT(I) STEP .5
5140 TERM1=.072*W(I,LC)*X*(LFT(I)^3-2*LFT(I)*X^2+X^3)/(ES*IE(I))
5150 TERM2=24*M(I,1)*X*(LFT(I)-X)*(2*LFT(I)-X)/(LFT(I)*ES*IE(I))
5160 TERM3=24*M(I,2)*LFT(I)*X*(1-X^2/LFT(I)^2)/(ES*IE(I))
5170 DSX=TERM1+TERM2+TERM3\ IF ABS(DSX)>DMAX THEN DMAX=ABS(DSX)
5180 NEXT X
5190 IF DMAX>LFT(I)*12/DSA(LCOND) THEN FLAG(I)=1\ REM Compare Max. to Allow.
5200 RETURN
! AISC 1.10.5.4 STIFFENER MOMENT OF INERTIA AND GROSS AREA REQUIREMENT
! Stiffener Moment of Inertia Requirement
5230 IW=IXS(I)+AST(I)*(DST(I)-YS(I)+T(I)/2)^2
5240 IF I=2 THEN LYT=LY(2)\LYB=LY(3)\ GOTO 5260
5250 LYT=LY(1)\LYB=LY(4)
5260 HWEB=12*LFT(I)-LYT-LYB\ IF IW<((HWEB/50)^4 GOTO 5350
! Stiffener Gross Area Requirement
5280 ALPHA=SS(I)/HWEB\K2=4+(5.34/ALPHA^2)\CV=45000*K2/(FYP*(HWEB/T(I))^2)
5290 IF CV>.8 THEN CV=190*SQR(K2/FYP)/(HWEB/T(I))
5300 FVAVG=WG*LSPAN/(4000*HWEB*T(I))\FVALL=FYP*CV/2.89
5310 IF FVALL>.4*FYP THEN FVALL=.4*FYP
5320 BETA=2.4*FVAVG/FVALL
5330 AREQ=(1-CV)*(ALPHA-ALPHA^2/SQR(1+ALPHA^2))*FYP*HWEB*T(I)*BETA/(2*FYS)
5340 IF AST(I)<AREQ THEN 5350 ELSE 5360
5350 FLAG(I)=1
5360 RETURN

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DUCT7.BAS

23:42

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SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT7
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO PERFORM CHECKS ON THE DUCT
40 REM   SECTION, WHERE THE DUCT SECTION IS CONSIDERED TO BE A SIMPLY
50 REM   SUPPORTED BENDING MEMBER
60 REM
70 PROGRAM DUCT7
80 LET I4=4
90 DIM AL(I4),LX(I4),LY(I4),YL(I4),T(I4),IL(I4),SS(I4),SSE(I4),WS(I4),WA(I4)
100 DIM LSEC$(I4),FVEND(I4),FVINT(I4)
110 OPEN 'LP:' FOR OUTPUT AS FILE #1\ OPEN 'DATA3' FOR INPUT AS FILE #3
120 OPEN 'DATA4' FOR INPUT AS FILE #4
130 INPUT #3,XX,XX$,XX,XX,EP,FYP
140 INPUT #3,UWP,QDL,XX,XX,XX,QS
150 INPUT #4,XX$,QDI,XX,XX,XX,XX,QLRD,QLAD
160 CLOSE #3,#4\ PRINT
170 PRINT 'DO YOU WANT A HARD COPY OF THE DUCT SECTION CHECK OUTPUT? (Y OR N)'
180 INPUT HCOPY$
190 CHNG1$='N'\CHNG2$='N'\CHNG3$='N'\CHNG4$='N'
200 IF HCOPY$='N' THEN PRINT CHR$(27)+'[?4i'\ GOTO 220
210 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
220 IF CHNG1$='Y' GOTO 290
230 IF CHNG2$='Y' OR CHNG3$='Y' OR CHNG4$='Y' THEN 340
240 PRINT \ PRINT \ PRINT TAB(30);'DUCT SECTION CHECKS'\ PRINT \ PRINT
250 PRINT 'THIS PROGRAM APPLIES TO DUCTS WITH RECTANGULAR CROSS SECTIONS ';
260 PRINT 'ONLY. DUCT'\ PRINT 'SECTION CHECKS FOR DUCTS WITH OTHER THAN ';
270 PRINT 'RECTANGULAR CROSS SECTIONS MUST BE'\ PRINT 'ACCOMPLISHED BY HAND.'
280 PRINT \ PRINT 'ENTER POISSON'S RATIO FOR THE DUCT PLATE'\ INPUT PR\ PRINT
290 PRINT 'ENTER THE DUCT WIDTH (INTERIOR HORIZONTAL DIMENSION) IN INCHES'
300 INPUT W\ PRINT
310 PRINT 'ENTER THE DUCT HEIGHT (INTERIOR VERTICAL DIMENSION) IN INCHES'
320 INPUT H\ PRINT
330 PRINT 'ENTER THE DUCT SECTION CLEAR SPAN IN FEET'\ INPUT LSPAN\ PRINT
340 PRINT 'ENTER THE PLATE THICKNESSES (NOT INCLUDING CORROSION ALLOWANCES) ';
350 PRINT 'OF SIDES 1, 2,\ PRINT '3 AND 4, IN DECIMALS OF AN INCH. (SIDE ';
360 PRINT '1 IS TOP PANEL, SIDES 2 AND 4 ARE SIDE'\ PRINT 'PANELS, SIDE 3 IS';
370 PRINT 'BOTTOM PANEL)'
380 INPUT T(1),T(2),T(3),T(4)\ PRINT
390 IF CHNG1$='Y' OR CHNG2$='Y' THEN 520
400 IF CHNG4$='Y' THEN 870
410 PRINT 'ENTER THE INTERIOR PANEL STIFFENER SPACINGS FOR SIDES 1 THROUGH';
420 PRINT ' 4 IN INCHES'\ INPUT SS(1),SS(2),SS(3),SS(4)\ PRINT
430 PRINT 'ENTER THE END PANEL STIFFENER SPACINGS FOR SIDES 1 THROUGH';
440 PRINT ' 4 IN INCHES'\ INPUT SSE(1),SSE(2),SSE(3),SSE(4)\ PRINT
450 IF CHNG3$='Y' THEN 870
460 PRINT 'ENTER THE NOMINAL STIFFENER WEIGHTS, IN PLF, FOR SIDES 1 THROUGH 4'
470 INPUT WS(1),WS(2),WS(3),WS(4)\ PRINT \ PRINT
480 PRINT 'ENTER THE UNIT WEIGHT OF THE CORNER ANGLES IN PCF'
490 INPUT UWA\ PRINT
500 IF HCOPY$='N' GOTO 520
510 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
520 PRINT 'ENTER THE EQUAL LEG CORNER ANGLES SELECTED FOR CORNERS 1, 2, ';
530 PRINT '3 AND 4'\ PRINT
540 PRINT 'NOTE: CORNER 1 IS THE "UPPER LEFT" CORNER OF THE DUCT, AND ';
550 PRINT 'CORNER NUMBERING'\ PRINT 'PROCEEDS CLOCKWISE AROUND THE DUCT. ';

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560 PRINT 'EXAMPLES OF THE INPUT FORMAT INCLUDE\' PRINT 'L3X3X4, L3.5X3.5';
570 PRINT 'X5, L4X4X8 AND L5X5X12, WHERE THE FIRST TWO NUMBERS IN THE INPUT'
580 PRINT 'STRING ARE THE ANGLE LEG LENGTHS, AND THE LAST NUMBER IS THE '
590 PRINT 'ANGLE THICKNESS IN\' PRINT 'SIXTEENTHS OF AN INCH. UNLESS SPE';
600 PRINT 'CIAL CONSIDERATIONS DICTATE OTHERWISE, ALL\' PRINT 'FOUR CORNE';
610 PRINT 'R ANGLES SHOULD BE THE SAME SIZE. THE LIGHTEST RECOMMENDED CORNER'
620 PRINT 'ANGLE IS L3X3X4.' PRINT
630 INPUT LSEC$(1),LSEC$(2),LSEC$(3),LSEC$(4)\ PRINT
640 REM Read in the corner angle section properties
650 ENDFILE=0\ FOR I=1 TO 4\AL(I)=0\ NEXT I
660 OPEN 'EA' FOR INPUT AS FILE #10
670 LINPUT #10,EA1%\ LINPUT #10,EA2%\ LINPUT #10,EA3%
680 LSEC%=MID$(EA1$,1%,10%)\AL=VAL(MID$(EA1$,18%,6%))
690 LY=VAL(MID$(EA1$,32%,3%))\LX=VAL(MID$(EA1$,45%,3%))
700 IL=VAL(MID$(EA2$,5%,6%))\YL=VAL(MID$(EA2$,45%,5%))
710 FOR I=1 TO 4\ IF LSEC$<>LSEC$(I) THEN 730
720 AL(I)=AL\LY(I)=LY\LX(I)=LX\IL(I)=IL\YL(I)=YL
730 NEXT I\ IF LSEC$='L8X8X16' THEN ENDFILE=1
740 FLAG=0\ FOR I=1 TO 4\ IF AL(I)=0 THEN FLAG=1
750 NEXT I
760 IF FLAG=1 AND ENDFILE=0 THEN 670
770 IF FLAG=1 AND ENDFILE=1 THEN 780 ELSE 870
780 FOR I=1 TO 4\ IF AL(I)<>0 THEN 810
790 PRINT 'THE ANGLE SECTION THAT YOU INPUT FOR CORNER';I;'IS NOT AVAILA';
800 PRINT 'BLE IN THIS PROGRAM\' PRINT
810 NEXT I\ PRINT 'PLEASE REENTER THE EQUAL LEG CORNER ANGLE SECTIONS\' PRINT
820 PRINT \ CLOSE #10\ IF HCOPI$='N' GOTO 840
830 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
840 GOTO 520
850 REM Calculate the uniformly distributed gravity load on the duct section
860 REM Compute the corner angle weights
870 CLOSE #10\ FOR I=1 TO 4\WA(I)=AL(I)*UWA/144\ NEXT I
880 REM Compute the uniform load
890 TERM1=((T(1)+T(3))*W+(T(2)+T(4))*H)*UMP/144+(QDI+QDL)*(W+H)/6
900 TERM2=WS(1)*W/SS(1)+WS(2)*H/SS(2)+WS(3)*W/SS(3)+WS(4)*H/SS(4)
910 IF QLRD>QS THEN TERM3=QLRD*W/12 ELSE TERM3=QS*W/12
920 TERM4=QLAD*W/12+WA(1)+WA(2)+WA(3)+WA(4)
930 WG=TERM1+TERM2+TERM3+TERM4
940 REM Calculate the effective compression flange stress
950 GOSUB 2770
960 IF FLAG=0 THEN 1000
970 PRINT \ PRINT \ PRINT 'THE EFFECTIVE COMPRESSION FLANGE STRESS COMPUTA';
980 PRINT 'TION FAILED\' PRINT \ PRINT
990 REM Calculate the reduced allowable flange stress
1000 IF T(2)<T(4) THEN T=T(2)\LYT=LY(2)\LXT=LX(2)\LYB=LY(3)\ALT=AL(2)\ GOTO 1050
1010 IF T(4)<T(2) THEN T=T(4)\LYT=LY(1)\LXT=LX(1)\LYB=LY(4)\ALT=AL(1)\ GOTO 1050
1020 IF LY(1)+LY(4)>LY(2)+LY(3) THEN 1040
1030 T=T(4)\LYT=LY(1)\LXT=LX(1)\LYB=LY(4)\ALT=AL(1)\ GOTO 1050
1040 T=T(2)\LYT=LY(2)\LXT=LX(2)\LYB=LY(3)\ALT=AL(2)
1050 FBR1=1-.0005*H*(T(2)+T(4))*((H-LYT-LYB)/T-760/SQR(.6*FYP))/(W*T(1))
1060 FBR=.6*FYP*FBR1
1070 IF CHNG1$='Y' THEN CHNG1$='N'
1080 IF CHNG2$='Y' THEN CHNG2$='N'
1090 IF CHNG3$='Y' THEN CHNG3$='N'
1100 IF CHNG4$='Y' THEN CHNG4$='N'
1110 FLAG1=0

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1120 REM   Compare effective compression flange stress to reduced allowable
1130 REM   flange stress
1140 IF FBE<=FBR THEN 1360 ELSE FLAG1=1
1150 PRINT \ PRINT
1160 PRINT 'THE EFFECTIVE COMPRESSION FLANGE STRESS IS GREATER THAN THE RED';
1170 PRINT 'UCED ALLOWABLE'\ PRINT 'FLANGE STRESS. YOU MUST EITHER INCREASE';
1180 PRINT ' THE DUCT SIDE AND/OR TOP PLATE THICK-\ PRINT 'NESSES, INCREASE';
1190 PRINT ' THE SIZE OF THE CORNER ANGLES, REDUCE THE DUCT CLEAR SPAN, OR'
1200 PRINT 'MODIFY THE DUCT CROSS SECTION DIMENSIONS TO PROVIDE A GREATER ';
1210 PRINT 'EFFECTIVE SECTION'\ PRINT 'MODULUS.\ PRINT \ PRINT
1220 PRINT 'DO YOU WISH TO MAKE ANY OF THESE CHANGES? (Y OR N)'\ INPUT CHNG1$
1230 PRINT \ IF CHNG1$='Y' GOTO 200
1240 PRINT \ PRINT \ PRINT TAB(30);'***** WARNING *****'
1250 PRINT '   THIS PROGRAM IS CONTINUING WITH THE DUCT SECTION CHECKS. ';
1260 PRINT 'HOWEVER, YOU'\ PRINT '   ARE WARNED THAT THE EFFECTIVE COMPRES';
1270 PRINT 'SSION FLANGE STRESS EXCEEDS THE'\ PRINT '   REDUCED ALLOWABLE';
1280 PRINT ' FLANGE STRESS. THE PRESENT DUCT CONFIGURATION SHOULD'
1290 PRINT '   NOT BE USED. RATHER, ONE, SOME OR ALL OF THE MODIFICATIONS';
1300 PRINT ' RECOMMENDED'\ PRINT '   ABOVE SHOULD BE MADE, AND THIS PROGR';
1310 PRINT 'AM SHOULD THEN BE REEXECUTED TO'\ PRINT '   CHECK THE ADEQUACY';
1320 PRINT ' OF THE MODIFIED DUCT SECTION.\ PRINT \ PRINT
1330 IF HCOPI$='N' GOTO 1360
1340 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
1350 REM   Check compression flange vertical buckling
1360 IF (H-LYT-LYB)/T<=2000/SQR(FYP) THEN 1590
1370 ACF=30*T^2+(LXT+BE/2)*T(1)+ALT
1380 FBVB=PI^2*EP^2*T^3/(24*(1-PR^2)*(H-LYT-LYB)*ACF*(16.5+FYP))
1390 IF FBE<=FBVB THEN 1590 ELSE FLAG1=1
1400 PRINT \ PRINT
1410 PRINT 'THE EFFECTIVE COMPRESSION FLANGE STRESS EXCEEDS THAT WHICH MAY ';
1420 PRINT 'CAUSE COMPRESSION'\ PRINT 'FLANGE VERTICAL BUCKLING. YOU MUST ';
1430 PRINT 'INCREASE THE DUCT SIDE PLATE THICKNESSES'\ PRINT 'AND/OR INCRE';
1440 PRINT 'ASE THE SIZE OF THE TOP CORNER ANGLES.\ PRINT \ PRINT
1450 PRINT 'DO YOU WISH TO MAKE EITHER OF THESE CHANGES? (Y OR N)'
1460 INPUT CHNG2$\ PRINT \ IF CHNG2$='Y' GOTO 200
1470 PRINT \ PRINT \ PRINT TAB(30);'***** WARNING *****'
1480 PRINT '   THIS PROGRAM IS CONTINUING WITH THE DUCT SECTION CHECKS. ';
1490 PRINT 'HOWEVER, YOU'\ PRINT '   ARE WARNED THAT THE EFFECTIVE COMPRES';
1500 PRINT 'SSION FLANGE STRESS EXCEEDS THAT'\ PRINT '   WHICH MAY CAUSE ';
1510 PRINT 'COMPRESSION FLANGE VERTICAL BUCKLING. THE PRESENT DUCT'
1520 PRINT '   CONFIGURATION SHOULD NOT BE USED. RATHER, ONE OR BOTH OF ';
1530 PRINT 'THE MODIFI-\ PRINT '   CATIONS RECOMMENDED ABOVE SHOULD BE MA';
1540 PRINT 'DE, AND THIS PROGRAM SHOULD THEN'\ PRINT '   BE REEXECUTED TO';
1550 PRINT ' CHECK THE ADEQUACY OF THE MODIFIED DUCT SECTION.\ PRINT \ PRINT
1560 IF HCOPI$='N' GOTO 1590
1570 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
1580 REM   Calculate allowable web shear stress
1590 FOR I=2 TO 4 STEP 2
1600 IF I=2 THEN T=T(2)\LYT=LY(2)\LYB=LY(3)\ GOTO 1630
1610 T=T(4)\LYT=LY(1)\LYB=LY(4)
1620 REM   End Panels
1630 K1=4+5.34/(SSE(I)/(H-LYT-LYB))^2
1640 CV=45000*K1/(FYP*((H-LYT-LYB)/T)^2)\ IF CV<.8 THEN 1660
1650 CV=190*SQR(K1/FYP)*T/(H-LYT-LYB)
1660 FVEND(I)=FYP*CV/2.89\ IF FVEND(I)>.4*FYP THEN FVEND(I)=.4*FYP
1670 REM   Interior Panels

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1680 K1=4+5.34/(SS(I)/(H-LYT-LYB))^2
1690 CV=45000*K1/(FYP*((H-LYT-LYB)/T)^2)\ IF CV<.8 THEN 1710
1700 CV=190*SQR(K1/FYP)*T/(H-LYT-LYB)
1710 FVINT(I)=FYP*CV/2.89
1720 IF FVINT(I)>.4*FYP THEN FVINT(I)=.4*FYP
1730 NEXT I
1740 REM Calculate average web shear stress
1750 REM End Panels
1760 FVAUGEND=WG*LSPAN/(2000*H*(T(2)+T(4)))
1770 REM Interior Panels
1780 IF LSPAN-H/2<0 THEN FVAUGINT=0\ GOTO 1810
1790 FVAUGINT=WG*(LSPAN-H/12)/((2000*H*(T(2)+T(4))))
1800 REM Compare average web shear stress to allowable web shear stress
1810 FLAG=0\ PRINT \ PRINT \ FOR I=2 TO 4 STEP 2
1820 IF FVAUGEND<=FVEND(I) THEN 1860
1830 FLAG=1\ PRINT 'THE AVERAGE WEB SHEAR STRESS IN THE END PANELS ON ' ;
1840 PRINT 'SIDE';I;'EXCEEDS THE ALLOWABLE'\ PRINT 'WEB SHEAR STRESS.' ;
1850 PRINT
1860 IF FVAUGINT<=FVINT(I) THEN 1900
1870 FLAG=1\ PRINT 'THE AVERAGE WEB SHEAR STRESS IN THE INTERIOR PANELS';
1880 PRINT ' ON SIDE';I;'EXCEEDS THE ALLOW-\ PRINT 'ABLE WEB SHEAR ' ;
1890 PRINT 'STRESS.'\ PRINT
1900 NEXT I
1910 IF FLAG=0 THEN 2100 ELSE FLAG1=1
1920 PRINT \ PRINT 'YOU MUST INCREASE THE DUCT SIDE PLATE THICKNESS OR DECREA';
1930 PRINT 'SE THE APPROPRIATE SIDE'\ PRINT 'STIFFENER SPACINGS IN ORDER TO ' ;
1940 PRINT 'ENSURE THAT AVERAGE WEB SHEAR STRESSES ARE LESS'\ PRINT 'THAN OR';
1950 PRINT ' EQUAL TO ALLOWABLE WEB SHEAR STRESSES.'\ PRINT \ PRINT
1960 PRINT 'DO YOU WISH TO MAKE EITHER OF THESE CHANGES? (Y OR N) '
1970 INPUT CHNG3%\ IF CHNG3%='Y' THEN 200
1980 PRINT \ PRINT \ PRINT TAB(30);'***** WARNING *****'
1990 PRINT ' THIS PROGRAM IS CONTINUING WITH THE DUCT SECTION CHECKS. ' ;
2000 PRINT 'HOWEVER, YOU'\ PRINT ' ARE WARNED THAT THE AVERAGE WEB SHEAR';
2010 PRINT ' STRESS EXCEEDS THE ALLOWABLE WEB'\ PRINT ' SHEAR STRESS AS ' ;
2020 PRINT 'NOTED ABOVE. THE PRESENT DUCT CONFIGURATION SHOULD NOT'
2030 PRINT ' BE USED. RATHER, ONE OR BOTH OF THE MODIFICATIONS RECOMMEN';
2040 PRINT 'DED ABOVE'\ PRINT ' SHOULD BE MADE, AND THIS PROGRAM SHOULD ' ;
2050 PRINT 'THEN BE REEXECUTED TO CHECK THE'\ PRINT ' ADEQUACY OF THE ' ;
2060 PRINT 'MODIFIED DUCT SECTION.'\ PRINT \ PRINT
2070 IF HCOPI%='N' GOTO 2100
2080 REM Check combined shear and tension stress
2090 REM Compute the maximum bending tensile stress in the web
2100 FBT=.0015*WG*LSPAN^2*(H+T(1)+T(3)-YY)/IBE
2110 REM Check against allowables
2120 FLAG=0\ PRINT \ PRINT \ FOR I=2 TO 4 STEP 2
2130 IF FBT<=(.825-.375*FVAUGINT/FVINT(I))*FYP THEN 2160
2140 FLAG=1\ PRINT 'THE COMBINED SHEAR AND TENSION STRESS IN SIDE';I;
2150 PRINT 'EXCEEDS THE ALLOWABLE'\ PRINT
2160 NEXT I\ IF FLAG=0 GOTO 2350 ELSE FLAG1=1
2170 PRINT \ PRINT 'YOU MUST INCREASE THE DUCT SIDE PLATE THICKNESS(ES) FOR ' ;
2180 PRINT 'THE SIDES(S) NOTED ABOVE'\ PRINT 'IN ORDER TO ENSURE THAT THE ' ;
2190 PRINT 'ALLOWABLE COMBINED SHEAR AND TENSION STRESS IN THE'
2200 PRINT 'WEB(S) IS NOT EXCEEDED'\ PRINT \ PRINT
2210 PRINT 'DO YOU WISH TO CHANGE EITHER DUCT SIDE PLATE THICKNESS? (Y OR N) '
2220 INPUT CHNG4%\ IF CHNG4%='Y' GOTO 200
2230 PRINT \ PRINT \ PRINT TAB(30);'***** WARNING *****'

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2240 PRINT '      THIS COMPLETES THE DUCT SECTION CHECK PORTION OF DESIGN. ';
2250 PRINT 'HOWEVER, YOU\' PRINT '      ARE WARNED THAT THE COMBINED SHEAR ';
2260 PRINT 'AND TENSION STRESS IN THE DUCT SIDE\' PRINT '      PANELS EXCEEDS';
2270 PRINT 'THE ALLOWABLE. THE PRESENT DUCT CONFIGURATION SHOULD';
2280 PRINT '      NOT BE USED. RATHER, THE SIDE PLATE THICKNESS(ES) NOTED ';
2290 PRINT 'ABOVE SHOULD\' PRINT '      BE INCREASED AND THIS PROGRAM SHOULD';
2300 PRINT 'THEN BE REEXECUTED TO CHECK THE\' PRINT '      MODIFIED DUCT ';
2310 PRINT 'SECTION.\' PRINT \ PRINT
2320 IF HCOPY$='N' GOTO 2350
2330 PRINT CHR$(27)+'[?4i\' PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
2340 REM Print out the results
2350 PRINT \ PRINT \ PRINT \ IF FLAG1=0 GOTO 2390
2360 PRINT 'THE DUCT SECTION SHOWN BELOW FAILS ONE OR MORE OF THE DUCT SECT';
2370 PRINT 'ION DESIGN\' PRINT 'CRITERIA FOR THE REASON(S) NOTED IN THE IMMED';
2380 PRINT 'IATELY PRECEDING WARNING(S).\ GOTO 2410
2390 PRINT 'ALL OF THE DUCT SECTION DESIGN CRITERIA A';
2400 PRINT 'RE MET FOR THE DUCT SECTION\' PRINT 'CONFIGURATION SHOWN BELOW'
2410 PRINT \ PRINT
2420 PRINT TAB(18);'DUCT WIDTH (INTERIOR DIMENSION):';TAB(53);W;'INCHES'
2430 PRINT TAB(18);'DUCT HEIGHT (INTERIOR DIMENSION):';TAB(53);H;'INCHES'
2440 PRINT TAB(18);'DUCT CLEAR SPAN:';TAB(53);LSPAN;'FEET'
2450 PRINT \ PRINT
2460 PRINT TAB(31);'SIDE 1';TAB(44);'SIDE 2';TAB(57);'SIDE 3';TAB(70);'SIDE 4'
2470 PRINT
2480 PRINT 'PLATE THICKNESS (INCHES)*';TAB(31);T(1);TAB(44);T(2);TAB(57);T(3);
2490 PRINT TAB(70);T(4)\ PRINT
2500 PRINT 'INTERIOR PANEL STIFFENER';TAB(32);SS(1);TAB(45);SS(2);TAB(58);
2510 PRINT SS(3);TAB(71);SS(4)\ PRINT 'SPACING (INCHES)'
2520 PRINT 'END PANEL STIFFENER';TAB(32);SSE(1);TAB(45);SSE(2);TAB(58);SSE(3);
2530 PRINT TAB(71);SSE(4)\ PRINT 'SPACING (INCHES)'
2540 PRINT 'NOMINAL STIFFENER';TAB(32);WS(1);TAB(45);WS(2);TAB(58);WS(3);
2550 PRINT TAB(71);WS(4)\ PRINT 'WEIGHT (PLF)\ PRINT
2560 PRINT '* NOT INCLUDING CORROSION ALLOWANCE\' PRINT \ PRINT
2570 PRINT TAB(30);'CORNER 1';TAB(43);'CORNER 2';TAB(56);'CORNER 3';TAB(69);
2580 PRINT 'CORNER 4\' PRINT \ PRINT 'CORNER ANGLE';TAB(31);LSEC$(1);TAB(44);
2590 PRINT LSEC$(2);TAB(57);LSEC$(3);TAB(70);LSEC$(4)\ PRINT \ PRINT \ PRINT
2600 PRINT 'DO YOU WISH TO REEXECUTE THIS PROGRAM (DUCT SECTION CHECKS)? ';
2610 PRINT '(Y OR N)\ INPUT REEX$ PRINT \ IF REEX$='Y' GOTO 190
2620 PRINT 'DO YOU WISH TO EXECUTE THE BEARING STIFFENER DESIGN PROGRAM?';
2630 PRINT '(Y OR N)\ INPUT BEARSTIFF$ PRINT
2640 IF BEARSTIFF$='N' GOTO 2740
2650 FOR I=1 TO 4\SS(I)=SSE(I)\ NEXT I
2660 LET C$=',\' OPEN 'DATA5' FOR OUTPUT AS FILE #5
2670 PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #5
2680 CLOSE #1\ LET IO=0
2690 DIM AL(IO),LX(IO),LY(IO),YL(IO),T(IO),IL(IO),SS(IO),SSE(IO),WS(IO),WA(IO)
2700 DIM LSEC$(IO),FVEND(IO),FVINT(IO)
2710 PRINT CHR$(27)+'[?4i\' PRINT 'COMMENCING BEARING STIFFENER DESIGN; ';
2720 PRINT 'CHAINING TO PROGRAM DUCT5; PLEASE WAIT'
2730 RECALC=2\ CHAIN 'DUCT5' WITH RECALC
2740 PRINT \ PRINT 'THIS CONCLUDES THE DUCTWORK STRUCTURAL DESIGN PROGRAM'
2750 CLOSE #1\ PRINT CHR$(27)+'[?4i\' END
2760 REM EFFECTIVE COMPRESSION FLANGE STRESS SUBROUTINE
2770 I=0\FBE=10\FLAG=0
2780 REM Calculate reduced effective compression flange width
2790 BE=(253*T(1)/SQR(FBE))*(1-50.3/((W-LX(1)-LX(2))*SQR(FBE)/T(1)))

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DUCT7.BAS

23:46

02-Apr-86

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2800 IF BE>W-LX(1)-LX(2) THEN BE=W-LX(1)-LX(2)
2810 REM   Calculate the location of the effective neutral axis
2820 A=(H+T(1)+T(3))*T(4)
2830 B=(H+T(1)+T(3))*T(2)
2840 C=(LX(1)+BE+LX(2))*T(1)
2850 D=(T(4)+H+T(2))*T(3)
2860 E=AL(1)*(T(1)+YL(1))
2870 F=AL(2)*(T(1)+YL(2))
2880 G=(T(1)+H+T(3))*A/2
2890 M=(T(1)+H+T(3))*B/2
2900 N=(T(1)+H+T(3))/2*D
2910 Q=AL(4)*(T(1)+H-YL(4))+AL(3)*(T(1)+H-YL(3))
2920 YY=(E+F+G+M+N+Q)/(A+B+C+D+AL(1)+AL(2)+AL(3)+AL(4))
2930 REM   Calculate the effective moment of inertia of the duct section
2940 IBE1=((T(2)+T(4))*(T(1)+H+T(3))^3)/12
2950 IBE2=(A+B)*(YY-(T(1)+H+T(3))/2)^2+C*(YY-T(1)/2)^2
2960 IBE3=D*(T(1)+H+T(3)/2-YY)^2+IL(1)+IL(2)+IL(3)+IL(4)
2970 IBE4=AL(1)*(YY-T(1)-YL(1))^2+AL(2)*(YY-T(1)-YL(2))^2
2980 IBE5=AL(3)*(T(1)+H-YL(3)-YY)^2+AL(4)*(T(1)+H-YL(4)-YY)^2
2990 IBE=IBE1+IBE2+IBE3+IBE4+IBE5
3000 REM   Compute compression flange maximum stress based on the reduced
3010 REM   effective compression flange width
3020 FBE1=.0015*WG*LSPAN^2*YY/IBE
3030 I=I+1
3040 IF I>100 THEN FLAG=1\ GOTO 3100
3050 REM   Test for closeness to assumed compression flange stress value
3060 IF ABS(FBE-FBE1)<.005 THEN GOTO 3100
3070 IF FBE>FBE1 THEN GOTO 3090
3080 FBE=ABS(FBE1+(FBE1-FBE)/2)\ GOTO 2790
3090 FBE=ABS(FBE1-(FBE-FBE1)/2)\ GOTO 2790
3100 RETURN

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DUCT8A.BAS

16:26

12-Mar-86

SET NO DOUBLE

10 REM PROGRAM NAME: DUCT8A

20 REM

30 REM THE PURPOSE OF THIS PROGRAM IS TO ENABLE PROGRAM DUCT5 TO CHAIN TO

40 REM PROGRAM DUCT8

50 REM

60 PROGRAM DUCT8A(RECALC)

70 CHAIN 'DUCT8' WITH RECALC

DUCT8.BAS

23:48

02-Apr-86

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SET NO DOUBLE
10 REM   PROGRAM NAME:  DUCT8
20 REM
30 REM   THE PURPOSE OF THIS PROGRAM IS TO SELECT THE BEARING STIFFENERS
40 REM
50 PROGRAM DUCT8(RECALC)
60 LET I2=2\I3=3\I4=4\I8=8\I12=12\I18=18\I36=36\ DIM SEC$(I4),AST(I4),FA(I4)
70 DIM WS(I4),WELD$(I4),LBRC(I4),FB(I4,I3,I2),FBM(I4,I3,I2),LY(I4),PLANGLE(I3)
80 DIM DST(I4),Y1(I4),IE(I4),RE(I4),BF(I4),TF(I4),TW(I4),RT(I4),AE(I4),IXS(I4)
90 DIM PVP(I4,I2,I2),FAM(I4,I2,I4),P(I4,I2,I4),DSA(I3),LFT(I4),T(I4),SS(I4)
100 DIM W1(I4,I18),W2(I4,I36),W3(I4,I12),M0(I4),A(I4,I4),B(I4,I8),D(I4),K1(I4)
110 DIM ANGDISP(I4),M(I4,I2),MMAXPOS(I4),MMAXNEG(I4),FAC(I4),FLAG(I4),PD(I4)
120 DIM QW(I4),QLR(I4),BE(I4),WA(I4),FLAG1(I4)
130 OPEN 'LP:' FOR OUTPUT AS FILE #1\ OPEN 'DATA3' FOR INPUT AS FILE #3
140 OPEN 'DATA4' FOR INPUT AS FILE #4\ OPEN 'DATA5' FOR INPUT AS FILE #5
150 INPUT #3,CLA,CORR$,CRA,LSPAN,EP,FYP,SEISZ
160 INPUT #3,UWP,QDL,QLA,QLP,QLV,QS,QXP,QXV
170 INPUT #3,LFT(1),LFT(2),LFT(3),LFT(4),QLR(1),QLR(3)
180 INPUT #3,T(1),T(2),T(3),T(4),QW(1),QW(2),QW(3),QW(4)
190 INPUT #4,HCOPY$,QDI,SHP,UWS,FYS,ES,QLRD,QLAD,WB
200 INPUT #4,LBRC(1),LBRC(2),LBRC(3),LBRC(4),WA(1),WA(2)
210 INPUT #4,WA(3),WA(4),DSA(1),DSA(2),DSA(3),LY(1),LY(2)
220 INPUT #4,LY(3),LY(4),WELD$(1),WELD$(2),WELD$(3),WELD$(4)
230 INPUT #5,SS(1),SS(2),SS(3),SS(4)\ CLOSE #3,#4,#5
240 OPEN 'DATA6' FOR INPUT AS FILE #6
250 FOR I=1 TO 18\ INPUT #6,W1(1,I),W1(2,I),W1(3,I),W1(4,I)\ NEXT I
260 FOR I=1 TO 36\ INPUT #6,W2(1,I),W2(2,I),W2(3,I),W2(4,I)\ NEXT I
270 FOR I=1 TO 12\ INPUT #6,W3(1,I),W3(2,I),W3(3,I),W3(4,I)\ NEXT I\ CLOSE #6
280 DEF FNTAN(RAD)=SIN(RAD)/COS(RAD)
290 REM Calculate stiffener axial forces due to internal vacuums and pressures
300 GOSUB 2760\ IF RECALC=3 THEN 2360
310 IF HCOPY$='N' GOTO 330
320 PRINT CHR$(27)+'[?4i'\ PRINT #1,CHR$(12)\ PRINT CHR$(27)+'[?5i'
330 AVAIL=0\ PRINT \ PRINT TAB(27);'BEARING STIFFENER DESIGN'\ PRINT \ PRINT
340 IF LFT(2)=LFT(4) THEN 510
350 PRINT TAB(30);'*** PLEASE NOTE ***'\ PRINT \ PRINT 'THE LENGTH OF SIDE 2 ' ;
360 PRINT 'IS DIFFERENT FROM THE LENGTH OF SIDE 4 FOR THIS DUCT CROSS'
370 PRINT 'SECTION. IN ORDER TO ENSURE THAT ADEQUATE RIGID FRAME STIFFENERS';
380 PRINT 'ARE SELECTED,'\ PRINT 'THIS SERIES OF PROGRAMS (STARTING WITH ' ;
390 PRINT 'PROGRAM DUCT1) SHOULD BE RUN TWICE. THE'\ PRINT 'FIRST RUN SHOULD';
400 PRINT 'DESIGNATE SIDE 2 AS THE LONGER SIDE AND SIDE 4 AS THE SHORTER'
410 PRINT 'SIDE. THE SECOND RUN SHOULD DESIGNATE SIDE 2 AS THE SHORTER SIDE ' ;
420 PRINT 'AND SIDE 4 AS'\ PRINT 'THE LONGER SIDE. SIDE 1 REMAINS THE TOP ' ;
430 PRINT 'AND SIDE 3 REMAINS THE BOTTOM FOR BOTH'\ PRINT 'RUNS. THE TWO RU';
440 PRINT 'NS SHOULD THEN BE COMPARED STIFFENER BY STIFFENER, AND THE'
450 PRINT 'HEAVIER STIFFENER SECTION IN EACH CASE SHOULD BE SELECTED WHEN ' ;
460 PRINT 'RIGID FRAME'\ PRINT 'STIFFENERS ARE DESIGNATED. THIS PROCEDURE';
470 PRINT 'IS REQUIRED SINCE THE RIGID FRAME'\ PRINT 'PROGRAM ALWAYS ' ;
480 PRINT 'DESIGNATES SIDE 4 AS THE WINDWARD SIDE OF THE DUCT. IT APPLIES'
490 PRINT 'ONLY TO RIGID FRAME STIFFENER DESIGN. THIS PROCEDURE DOES NOT ' ;
500 PRINT 'APPLY TO PINNED-\ PRINT 'END STIFFENER DESIGN.\ PRINT \ PRINT
510 PRINT 'WHAT SHAPE BEARING STIFFENERS DO YOU WISH TO USE? (W = W SHAPE,'
520 PRINT 'WT = STRUCTURAL TEE, C = CHANNEL)'\ INPUT SHP\ PRINT
530 IF SHP$='W' THEN SHP=1 ELSE SHP=0
540 IF SHP$='WT' THEN SHP=2
550 IF SHP$='C' THEN SHP=3

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DUCT8.BAS

15:16

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560 IF SHP=0 THEN 510
570 PRINT 'ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS'
580 PRINT '(REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED ';
590 PRINT 'TO HAVE THE\' \ PRINT 'SAME NOMINAL DEPTH)\' INPUT TRIALND\ PRINT
600 REM Test to insure that chosen trial nominal depth is available
610 ON SHP GOTO 620,660,710
620 IF TRIALND=6 OR TRIALND=8 OR TRIALND=10 THEN AVAIL=1\ GOTO 740
630 IF TRIALND=12 OR TRIALND=14 OR TRIALND=16 THEN AVAIL=1\ GOTO 740
640 IF TRIALND=18 OR TRIALND=21 OR TRIALND=24 THEN AVAIL=1\ GOTO 740
650 GOTO 740
660 IF TRIALND=3 OR TRIALND=4 OR TRIALND=5 THEN AVAIL=1\ GOTO 740
670 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 740
680 IF TRIALND=9 OR TRIALND=10.5 OR TRIALND=12 THEN AVAIL=1\ GOTO 740
690 IF TRIALND=13.5 OR TRIALND=15 OR TRIALND=16.5 THEN AVAIL=1\ GOTO 740
700 GOTO 740
710 IF TRIALND=6 OR TRIALND=7 OR TRIALND=8 THEN AVAIL=1\ GOTO 740
720 IF TRIALND=9 OR TRIALND=10 OR TRIALND=12 THEN AVAIL=1\ GOTO 740
730 IF TRIALND=15 THEN AVAIL=1
740 IF AVAIL=1 GOTO 790
750 PRINT \ PRINT 'THE TRIAL NOMINAL DEPTH THAT YOU HAVE CHOSEN IS NOT ';
760 PRINT 'AVAILABLE IN THIS DESIGN\' \ PRINT 'PROGRAM FOR THE STIFFENER ';
770 PRINT 'SHAPE THAT YOU HAVE SELECTED. PLEASE ENTER A'
780 PRINT 'DIFFERENT TRIAL NOMINAL DEPTH.\' GOTO 310
790 IF HCOPI$='N' THEN 800 ELSE PRINT CHR$(27)+'[?4i'
800 PRINT 'RIGID FRAME BEARING STIFFENERS ARE BEING SELECTED. THIS PROCE';
810 PRINT 'SS MAY TAKE\' \ PRINT 'FROM 30 SECONDS TO TWO HOURS. THE LOAD CON';
820 PRINT 'DITION, LOAD CASE AND STIFFENER\' \ PRINT 'SECTION PRINTOUTS TO THIS';
830 PRINT ' SCREEN (WHICH WILL COMMENCE MOMENTARILY) MAY BE DIS-';
840 PRINT 'REGARDED. THEY ARE PROVIDED SIMPLY TO GIVE YOU SOME IDEA OF THE ';
850 PRINT 'STIFFENER\' \ PRINT 'SELECTION PROGRESS, AND TO REASSURE YOU THAT ';
860 PRINT 'THIS PROGRAM IS NOT "LOST". THE\' \ PRINT 'FINAL STIFFENER SECTION';
870 PRINT ' SELECTION WILL BE PRINTED OUT ON THE LINE PRINTER (IF'
880 PRINT 'YOU REQUESTED A HARD COPY OF THE STIFFENER SELECTION OUTPUT). ';
890 PRINT 'PLEASE WAIT.\' PRINT
900 FOR I=1 TO 4\ SEC$(I)='*****'\ WS(I)=0\ FLAG1(I)=0\ NEXT I
910 MAXWT=0\ ON SHP GOTO 920,930,940
920 OPEN 'WSHAPE' FOR INPUT AS FILE #10\ GOTO 960
930 OPEN 'WT' FOR INPUT AS FILE #10\ GOTO 960
940 OPEN 'C' FOR INPUT AS FILE #10
950 REM End of File Check
960 IF MAXWT=1 THEN CLOSE #10\ GOTO 2480
970 REM Read W, WT, or Channel shape properties
980 ON SHP GOTO 990,1000,1010
990 GOSUB 2880\ GOTO 1020
1000 GOSUB 2970\ GOTO 1020
1010 GOSUB 3040
1020 IF NDST<>TRIALND GOTO 980
1030 REM Check to see if section is heaviest possible section for that
1040 REM nominal depth
1050 IF MAXND=TRIALND THEN MAXWT=1
1060 FOR I=1 TO 4\ IF SEC$(I)<>'*****' THEN 1130
1070 REM Calculate effective section properties
1080 GOSUB 3120\ AST(I)=AST\ DST(I)=DST\ BF(I)=BF\ TF(I)=TF\ TW(I)=TW
1090 RT(I)=RT\ IXS(I)=IXS\ YS(I)=YS
1100 REM Calculate trial stiffener weights
1110 WS(I)=AST*UWS/144

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1120 REM Calculate allowable stiffener axial compressive stresses
1130 GOSUB 3220\ NEXT I
1140 REM Calculate stiffener axial load and stress combinations
1150 GOSUB 3320
1160 FOR LCOND=1 TO 3
1170   ON LCOND GOTO 1180,1190,1200
1180   LCASE=18\ GOTO 1210
1190   LCASE=36\ GOTO 1210
1200   LCASE=12
1210   DIM W(I4,LCASE)
1220   FOR LC=1 TO LCASE
1230     REM Calculate stiffener fixed-end moments
1240     FOR I=1 TO 4\ ON LCOND GOTO 1250,1260,1270
1250       W(I,LC)=W1(I,LC)\ GOTO 1280
1260       W(I,LC)=W2(I,LC)\ GOTO 1280
1270       W(I,LC)=W3(I,LC)
1280     M0(I)=W(I,LC)*LFT(I)^2/1000\ NEXT I
1290     REM Calculate rigid frame stiffener end moments
1300     GOSUB 3580
1310     REM Calculate maximum positive and negative stiffener moments and
1320     REM maximum stiffener and plate bending stresses
1330     GOSUB 4080
1340     REM Match transverse loading cases with appropriate axial loading
1350     REM combination
1360     ON LCOND GOTO 1370,1440,1540
1370     IF LC<>1 AND LC<>2 AND LC<>3 AND LC<>4 THEN 1390
1380     FOR I=1 TO 4\FAC(I)=FAM(I,1,1)\ NEXT I\ GOTO 1600
1390     IF LC<>5 AND LC<>7 AND LC<>9 AND LC<>11 THEN 1410
1400     FOR I=1 TO 4\FAC(I)=FAM(I,1,2)\ NEXT I\ GOTO 1600
1410     IF LC<>6 AND LC<>8 AND LC<>10 AND LC<>12 THEN 1430
1420     FOR I=1 TO 4\FAC(I)=FAM(I,1,3)\ NEXT I\ GOTO 1600
1430     FOR I=1 TO 4\FAC(I)=FAM(I,1,4)\ NEXT I\ GOTO 1600
1440     IF LC=1 OR LC=2 OR LC=3 OR LC=4 GOTO 1460
1450     IF LC<>5 AND LC<>6 AND LC<>7 AND LC<>8 THEN 1470
1460     FOR I=1 TO 4\FAC(I)=FAM(I,1,1)\ NEXT I\ GOTO 1600
1470     IF LC=9 OR LC=11 OR LC=13 OR LC=15 GOTO 1490
1480     IF LC<>17 AND LC<>19 AND LC<>21 AND LC<>23 THEN 1500
1490     FOR I=1 TO 4\FAC(I)=FAM(I,1,2)\ NEXT I\ GOTO 1600
1500     IF LC=10 OR LC=12 OR LC=14 OR LC=16 GOTO 1520
1510     IF LC<>18 AND LC<>20 AND LC<>22 AND LC<>24 THEN 1530
1520     FOR I=1 TO 4\FAC(I)=FAM(I,1,3)\ NEXT I\ GOTO 1600
1530     FOR I=1 TO 4\FAC(I)=FAM(I,1,4)\ NEXT I\ GOTO 1600
1540     IF LC<>1 AND LC<>2 AND LC<>3 AND LC<>4 THEN 1560
1550     FOR I=1 TO 4\FAC(I)=FAM(I,2,1)\ NEXT I\ GOTO 1600
1560     IF LC<>5 AND LC<>7 AND LC<>9 AND LC<>11 THEN 1580
1570     FOR I=1 TO 4\FAC(I)=FAM(I,2,2)\ NEXT I\ GOTO 1600
1580     FOR I=1 TO 4\FAC(I)=FAM(I,2,3)\ NEXT I
1590     REM Calculate allowable stiffener and adj. plate bending stresses
1600     FOR I=1 TO 4\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1620
1610     GOSUB 4250
1620     NEXT I
1630     REM Check interaction formulas
1640     FOR I=1 TO 4\FLAG(I)=0\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1660
1650     GOSUB 4680
1660     NEXT I
1670     FLAG1=1\FLAG2=0\ FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'

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1680     IF SEC$(I)='*****' THEN FLAG1=0
1690     IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1700     NEXT I\ IF FLAG1=1 AND FLAG2=1 THEN 1980
1710     REM    Check stiffener deflections
1720     REM    Calculate stiffener fixed-end moments (incl. axial forces)
1730     FOR I=1 TO 4\ PD(I)=FAC(I)*AE(I)*1000\ IF PD(I)<=0 THEN 1760
1740         K1(I)=SQR(PD(I)/(1000*ES*IE(I)))\ TERM1=6*K1(I)*LFT(I)
1750         M0(I)=W(I,LC)*(1-TERM1/FNTAN(TERM1))/12000*K1(I)^2\ GOTO 1770
1760         M0(I)=W(I,LC)*LFT(I)^2/1000
1770     NEXT I
1780     REM    Calculate stiffener end moments (incl. axial forces)
1790     GOSUB 3580
1800     REM    Calculate and check maximum stiffener and plate deflections
1810     FOR I=1 TO 4\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1830
1820         GOSUB 5120
1830     NEXT I
1840     FLAG1=1\ FLAG2=0\ FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'
1850         IF SEC$(I)='*****' THEN FLAG1=0
1860         IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1870     NEXT I\ IF FLAG1=1 AND FLAG2=1 THEN 1980
1880     REM    Check stiffener moment of inertia and gross area requirements
1890     REM    (vertical stiffeners only)
1900     FOR I=2 TO 4 STEP 2\ IF SEC$(I)='FAILED' OR FLAG1(I)=1 THEN 1920
1910         GOSUB 5330
1920     NEXT I
1930     FLAG1=1\ FLAG2=0
1940     FOR I=1 TO 4\ IF FLAG(I)=1 THEN SEC$(I)='FAILED'
1950         IF SEC$(I)='*****' THEN FLAG1=0
1960         IF SEC$(I)='*****' OR SEC$(I)='FAILED' THEN FLAG2=1
1970     NEXT I\ IF FLAG1=0 OR FLAG2=0 THEN 1990
1980     LC=LCASE\ LCOND=3
1990     PRINT 'LOAD CASE';LC,SECT$;TAB(29);SEC$(1);TAB(42);SEC$(2);TAB(55);
2000     PRINT SEC$(3);TAB(68);SEC$(4)\ NEXT LC
2010     PRINT 'LOAD CONDITION';LCOND\ NEXT LCOND
2020     FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)<>'*****' GOTO 2040
2030     SEC$(I)=SECT$\ GOTO 2070
2040     IF SEC$(I)<>'FAILED' GOTO 2070
2050     IF RECALC=3 THEN FLAG3=1
2060     SEC$(I)='*****'\ FLAG=1\ GOTO 2080
2070     FLAG1(I)=1
2080     NEXT I\ IF FLAG=1 GOTO 960
2090     CLOSE #10\ IF RECALC=3 AND FLAG3=0 THEN 2480
2100     REM    Ensure that side stiffeners are the same size if lengths are equal
2110     IF LFT(2)<>LFT(4) OR WS(2)=WS(4) THEN 2200
2120     IF WS(2)<WS(4) THEN 2160
2130     SEC$(4)=SEC$(2)\ AST(4)=AST(2)\ DST(4)=DST(2)\ BF(4)=BF(2)\ TF(4)=TF(2)
2140     TW(4)=TW(2)\ RT(4)=RT(2)\ IXS(4)=ISX(2)\ WS(4)=WS(2)\ AE(4)=AE(2)
2150     Y1(4)=Y1(2)\ IE(4)=IE(2)\ RE(4)=RE(2)\ YS(4)=YS(2)\ GOTO 2200
2160     SEC$(2)=SEC$(4)\ AST(2)=AST(4)\ DST(2)=DST(4)\ BF(2)=BF(4)\ TF(2)=TF(4)
2170     TW(2)=TW(4)\ RT(2)=RT(4)\ IXS(2)=ISX(4)\ WS(2)=WS(4)\ AE(2)=AE(4)
2180     Y1(2)=Y1(4)\ IE(2)=IE(4)\ RE(2)=RE(4)\ YS(2)=YS(4)
2190     REM    Recalculate transverse loads using actual stiffener weights
2200     OPEN 'DATA5' FOR OUTPUT AS FILE #5
2210     C$=', '\ PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #5
2220     OPEN 'DATA7' FOR OUTPUT AS FILE #7
2230     PRINT #7,WS(1);C$;WS(2);C$;WS(3);C$;WS(4)\ CLOSE #7

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2240 OPEN 'DATA8' FOR OUTPUT AS FILE #8
2250 FOR I=1 TO 4\ PRINT #8,SEC$(I);C$;AST(I);C$;DST(I);C$;BF(I);C$;TF(I)
2260 PRINT #8,TW(I);C$;RT(I);C$;IXS(I);C$;AE(I);C$;IE(I);C$;RE(I);C$;Y1(I)
2270 PRINT #8,YS(I)\NEXT I\ PRINT #8,TRIALND\ CLOSE #8\I0=0\ DIM FLAG1(I0)
2280 DIM SEC$(I0),AST(I0),FA(I0),WA(I0),QW(I0),QLR(I0),BE(I0),WS(I0),Y1(I0)
2290 DIM WELD$(I0),LBRC(I0),FB(I0,I0,I0),FBM(I0,I0,I0),LY(I0),PLANGLE(I0)
2300 DIM DST(I0),IE(I0),RE(I0),BF(I0),TF(I0),TW(I0),RT(I0),AE(I0),IXS(I0)
2310 DIM W1(I0,I0),W2(I0,I0),W3(I0,I0),M0(I0),A(I0,I0),B(I0,I0),D(I0),K1(I0)
2320 DIM ANGDISP(I0),M(I0,I0),MMAXPOS(I0),MMAXNEG(I0),FAC(I0),FLAG(I0),PD(I0)
2330 PRINT \ PRINT 'CHAINING TO DUCT5 TO RECALCULATE TRANSVERSE LOADS BASED ON'
2340 PRINT 'ACTUAL STIFFENER WEIGHTS; PLEASE WAIT'
2350 CLOSE #1\RECALC=3\ CHAIN 'DUCT5' WITH RECALC
2360 OPEN 'DATA7' FOR INPUT AS FILE #7\ OPEN 'DATA8' FOR INPUT AS FILE #8
2370 INPUT #7,WS(1),WS(2),WS(3),WS(4)\ CLOSE #7
2380 FOR I=1 TO 4\ INPUT #8,SEC$(I),AST(I),DST(I),BF(I),TF(I)
2390 INPUT #8,TW(I),RT(I),IXS(I),AE(I),IE(I),RE(I),Y1(I)\ INPUT #8,YS(I)
2400 NEXT I\ INPUT #8,TRIALND\ CLOSE #8
2410 MAXWT=0\ ON SHP GOTO 2420,2430,2440
2420     OPEN 'WSHAPE' FOR INPUT AS FILE #10\ GOTO 2460
2430     OPEN 'WT' FOR INPUT AS FILE #10\ GOTO 2460
2440     OPEN 'C' FOR INPUT AS FILE #10
2450 REM   Recalculate allowable stiffener axial compressive stresses
2460 FOR I=1 TO 4\ GOSUB 3220\FLAG1(I)=0\ NEXT I
2470 FLAG3=0\ GOTO 1150
2480 IF HCOPIY$='Y' THEN PRINT CHR$(27)+'[?5i'
2490 PRINT \ PRINT TAB(34);'RIGID FRAME BEARING STIFFENERS'\ PRINT
2500 PRINT TAB(23);'SIDE 1';TAB(38);'SIDE 2';TAB(53);'SIDE 3';TAB(68);'SIDE 4'
2510 PRINT \ PRINT 'STIFFENER SECTION';TAB(21);
2520 FOR I=1 TO 4\ PRINT USING 'CCCCCCCCC ',SEC$(I);\ NEXT I
2530 PRINT \ PRINT \ PRINT
2540 FLAG=0\ FOR I=1 TO 4\ IF SEC$(I)='*****' THEN FLAG=1
2550 NEXT I\ IF FLAG=0 GOTO 2600
2560 PRINT 'NOTE:  "*****" INDICATES THAT AN ADEQUATE RIGID FRAME BEARING ST';
2570 PRINT 'IFFENER WITH\ PRINT TAB(6);TRIALND;'INCH NOMINAL DEPTH DOES NOT ';
2580 PRINT 'EXIST.  YOU MUST SELECT STIFFENER\ PRINT TAB(7);'SECTIONS WITH ';
2590 PRINT 'A GREATER NOMINAL DEPTH.\ PRINT \ PRINT
2600 PRINT 'DO YOU WISH TO SELECT RIGID FRAME BEARING STIFFENERS WITH A ';
2610 PRINT 'DIFFERENT\ PRINT 'NOMINAL DEPTH? (Y OR N)'
2620 INPUT DIFF$\ PRINT \ PRINT
2630 IF DIFF$='Y' THEN RECALC=2\ GOTO 310
2640 C$=', '\ OPEN 'DATA5' FOR OUTPUT AS FILE #5
2650 PRINT #5,SS(1);C$;SS(2);C$;SS(3);C$;SS(4)\ CLOSE #5\I0=0\ DIM FLAG1(I0)
2660 DIM SEC$(I0),AST(I0),FA(I0),QW(I0),QLR(I0),BE(I0),WA(I0),WS(I0),DST(I0)
2670 DIM WELD$(I0),LBRC(I0),FB(I0,I0,I0),FBM(I0,I0,I0),LY(I0),PLANGLE(I0)
2680 DIM Y1(I0),IE(I0),RE(I0),BF(I0),TF(I0),TW(I0),RT(I0),AE(I0),IXS(I0)
2690 DIM PVP(I0,I0,I0),FAM(I0,I0,I0),P(I0,I0,I0),DSA(I0),LFT(I0),T(I0),SS(I0)
2700 DIM W1(I0,I0),W2(I0,I0),W3(I0,I0),M0(I0),A(I0,I0),B(I0,I0),D(I0),K1(I0)
2710 DIM ANGDISP(I0),M(I0,I0),MMAXPOS(I0),MMAXNEG(I0),FAC(I0),FLAG(I0),PD(I0)
2720 PRINT \ PRINT \ PRINT 'THIS CONCLUDES THE DUCTWORK STRUCTURAL DESIGN ';
2730 PRINT 'PROGRAM'
2740 PRINT CHR$(27)+'[?4i'\ CLOSE #1\ END
2750 REM   AXIAL FORCE DUE TO INTERNAL VACUUM OR PRESSURE
2760 FOR I=1 TO 4
2770     ON I GOTO 2780,2820,2780,2820
2780     PVP(I,1,1)=QLV*SS(I)*(LFT(2)+LFT(4))/48
2790     PVP(I,2,1)=QXV*SS(I)*(LFT(2)+LFT(4))/48

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2800 PVP(I,1,2)=-QLP*SS(I)*(LFT(2)+LFT(4))/48
2810 PVP(I,2,2)=-QXP*SS(I)*(LFT(2)+LFT(4))/48\ GOTO 2860
2820 PVP(I,1,1)=QLV*SS(I)*(LFT(1)+LFT(3))/48
2830 PVP(I,2,1)=QXV*SS(I)*(LFT(1)+LFT(3))/48
2840 PVP(I,1,2)=-QLP*SS(I)*(LFT(1)+LFT(3))/48
2850 PVP(I,2,2)=-QXP*SS(I)*(LFT(1)+LFT(3))/48
2860 NEXT I\ RETURN
2870 REM W SHAPE PROPERTY RETRIEVAL SUBROUTINE
2880 LINPUT #10,WSHAPE1$\ LINPUT #10,WSHAPE2$
2890 LINPUT #10,WSHAPE3$\ LINPUT #10,WSHAPE4$
2900 SECT$=MID$(WSHAPE1$,1,7)\AST=VAL(MID$(WSHAPE1$,15,6))
2910 DST=VAL(MID$(WSHAPE1$,29,5))\NDST=VAL(MID$(WSHAPE1$,42,2))
2920 MAXND=VAL(MID$(WSHAPE1$,53,2))\TW=VAL(MID$(WSHAPE1$,56,4))
2930 BF=VAL(MID$(WSHAPE1$,68,5))\TF=VAL(MID$(WSHAPE2$,6,5))
2940 RT=VAL(MID$(WSHAPE2$,45,4))\IXS=VAL(MID$(WSHAPE2$,54,7))
2950 YS=DST/2\ RETURN
2960 REM WT PROPERTY RETRIEVAL SUBROUTINE
2970 LINPUT #10,WT1$\ LINPUT #10,WT2$\ LINPUT #10,WT3$\SECT$=MID$(WT1$,1,12)
2980 AST=VAL(MID$(WT1$,18,5))\DST=VAL(MID$(WT1$,31,5))
2990 NDST=VAL(MID$(WT1$,44,4))\MAXND=VAL(MID$(WT1$,53,4))
3000 TW=VAL(MID$(WT1$,58,4))\BF=VAL(MID$(WT1$,70,5))
3010 TF=VAL(MID$(WT2$,6,5))\RT=VAL(MID$(WT2$,45,4))
3020 IXS=VAL(MID$(WT2$,56,6))\YS=VAL(MID$(WT3$,19,5))\ RETURN
3030 REM CHANNEL PROPERTY RETRIEVAL SUBROUTINE
3040 LINPUT #10,C1$\ LINPUT #10,C2$\ LINPUT #10,C3$
3050 SECT$=MID$(C1$,1,8)\AST=VAL(MID$(C1$,18,5))
3060 DST=VAL(MID$(C1$,31,5))\NDST=VAL(MID$(C1$,31,2))
3070 MAXND=VAL(MID$(C1$,41,2))\TW=VAL(MID$(C1$,46,4))
3080 BF=VAL(MID$(C1$,58,5))\TF=VAL(MID$(C1$,72,4))
3090 IXS=VAL(MID$(C2$,56,6))\YS=DST/2\ RETURN
3100 REM STIFFENER EFFECTIVE SECTION PROPERTIES SUBROUTINE
3110 REM Determine the effective plate width, BE(I)
3120 BE(I)=12*T(I)
3130 REM Determine area of combined stiffener and effective plate, AE(I)
3140 AE(I)=AST+BE(I)*T(I)
3150 REM Determine the distance to the effective centroidal axis, Y1(I)
3160 Y1(I)=(AST*YS+BE(I)*T(I)*(DST+T(I)/2))/AE(I)
3170 REM Determine the effective moment of inertia, IE(I)
3180 IE(I)=IXS+AST*(Y1(I)-YS)^2+BE(I)*T(I)*(T(I)^2/12+(DST+T(I)/2-Y1(I))^2)
3190 REM Determine the effective radius of gyration, RE(I)
3200 RE(I)=SQR(IE(I)/AE(I))\ RETURN
3210 REM ALLOWABLE AXIAL COMPRESSIVE STRESS SUBROUTINE
3220 CC=SQR(2*PI^2*ES/FYS)
3230 IF 14.4*LFT(I)/RE(I)>CC GOTO 3290
3240 IF SHP=3 THEN IF BF(I)/TF(I)>95/SQR(FYS) THEN 3290 ELSE 3260
3250 IF BF(I)/((2*TF(I))>95/SQR(FYS) GOTO 3290
3260 TERM1=(1-((14.4*LFT(I)/RE(I))^2)/(2*CC^2))*FYS
3270 TERM2=5/3+5.4*LFT(I)/(RE(I)*CC)-373.25*(LFT(I)/RE(I))^3/CC^3
3280 FA(I)=TERM1/TERM2\ GOTO 3300
3290 FA(I)=PI^2*ES/(397.44*(LFT(I)/RE(I))^2)
3300 RETURN
3310 REM RIGID FRAME STIFFENER AXIAL FORCE AND AXIAL STRESS SUBROUTINE
3320 IF CORR$='N' THEN 3350
3330 FOR I=1 TO 4\T(I)=T(I)+CRA\ NEXT I
3340 REM Axial Force due to Tension Field Action
3350 TERM1=(T(1)*LFT(1)+T(2)*LFT(2)+T(3)*LFT(3)+T(4)*LFT(4))*UWP/12

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3360 TERM2=(QDI+QDL)*(LFT(1)+LFT(2)+LFT(3)+LFT(4))
3370 TERM3=(WS(1)*LFT(1)/SS(1)+WS(2)*LFT(2)/SS(2))*12
3380 TERM4=(WS(3)*LFT(3)/SS(3)+WS(4)*LFT(4)/SS(4))*12
3390 IF QLRD>QS THEN TERM5=QLRD*LFT(1) ELSE TERM5=QS*LFT(1)
3400 TERM6=QLAD*LFT(3)+WA(1)+WA(2)+WA(3)+WA(4)
3410 WG=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6\PS=(WG*LSPAN+WB)/4
3420 REM      Calculate Axial Load Combinations
3430 FOR J=1 TO 2\ P(1,J,1)=PVP(1,J,1)\ P(2,J,1)=PVP(2,J,1)+PS
3440      P(3,J,1)=PVP(3,J,1)\ P(4,J,1)=PVP(4,J,1)+PS
3450      P(1,J,2)=PVP(1,J,2)\ P(2,J,2)=PVP(2,J,2)
3460      P(3,J,2)=PVP(3,J,2)\ P(4,J,2)=PVP(4,J,2)
3470      P(1,J,3)=PVP(1,J,2)\ P(2,J,3)=PS
3480      P(3,J,3)=PVP(3,J,2)\ P(4,J,3)=PS
3490      P(1,J,4)=0\ P(2,J,4)=PS\ P(3,J,4)=0\ P(4,J,4)=PS\ NEXT J
3500 REM      Calculate Axial Stress Combinations
3510 FOR I=1 TO 4\ FOR J=1 TO 2\ FOR K=1 TO 4
3520      FAM(I,J,K)=P(I,J,K)/(AE(I)*1000)\ NEXT K\ NEXT J\ NEXT I
3530 IF CORR$='N' GOTO 3550
3540 FOR I=1 TO 4\ T(I)=T(I)-CRA\ NEXT I
3550 RETURN
3560 REM      RIGID FRAME STIFFENER END MOMENT SUBROUTINE
3570 REM      Fill Matrix A, the coefficient matrix
3580 A(1,1)=2*(IE(4)/LFT(4)+IE(1)/LFT(1))\ A(1,2)=IE(1)/LFT(1)\ A(1,3)=0
3590 A(1,4)=IE(4)/LFT(4)\ A(2,1)=IE(1)/LFT(1)
3600 A(2,2)=2*(IE(1)/LFT(1)+IE(2)/LFT(2))\ A(2,3)=IE(2)/LFT(2)\ A(2,4)=0
3610 A(3,1)=0\ A(3,2)=IE(2)/LFT(2)\ A(3,3)=2*(IE(2)/LFT(2)+IE(3)/LFT(3))
3620 A(3,4)=IE(3)/LFT(3)\ A(4,1)=IE(4)/LFT(4)\ A(4,2)=0
3630 A(4,3)=IE(3)/LFT(3)\ A(4,4)=2*(IE(3)/LFT(3)+IE(4)/LFT(4))
3640 REM      Fill Vector D, the constant vector
3650 D(1)=6*(M0(1)-M0(4))/ES\ D(2)=6*(M0(2)-M0(1))/ES
3660 D(3)=6*(M0(3)-M0(2))/ES\ D(4)=6*(M0(4)-M0(3))/ES
3670 REM      Go to inversion subroutine to find "A" Inverse
3680 GOSUB 3840
3690 REM      Multiply A inverse by Vector D to find corner angular displacements
3700 FOR I=1 TO 4\ ANGDISP(I)=0
3710      FOR K=1 TO 4\ ANGDISP(I)=ANGDISP(I)+B(I,K)*D(K)\ NEXT K\ NEXT I
3720 REM      Plug into slope-deflection equations to get stiffener end moments
3730 M(1,1)=-M0(1)+ES*IE(1)*(2*ANGDISP(1)+ANGDISP(2))/(6*LFT(1))
3740 M(1,2)=M0(1)+ES*IE(1)*(2*ANGDISP(2)+ANGDISP(1))/(6*LFT(1))
3750 M(2,1)=-M0(2)+ES*IE(2)*(2*ANGDISP(2)+ANGDISP(3))/(6*LFT(2))
3760 M(2,2)=M0(2)+ES*IE(2)*(2*ANGDISP(3)+ANGDISP(2))/(6*LFT(2))
3770 M(3,1)=-M0(3)+ES*IE(3)*(2*ANGDISP(3)+ANGDISP(4))/(6*LFT(3))
3780 M(3,2)=M0(3)+ES*IE(3)*(2*ANGDISP(4)+ANGDISP(3))/(6*LFT(3))
3790 M(4,1)=-M0(4)+ES*IE(4)*(2*ANGDISP(4)+ANGDISP(1))/(6*LFT(4))
3800 M(4,2)=M0(4)+ES*IE(4)*(2*ANGDISP(1)+ANGDISP(4))/(6*LFT(4))\ RETURN
3810 REM      MATRIX INVERSION SUBROUTINE
3820 REM      Gauss-Jordan Elimination (Matrix A is input, Matrix B is output)
3830 REM      First, create Matrix B, with A on the left and I on the right
3840 FOR I=1 TO 4\ FOR J=1 TO 4\ B(I,J+4)=0\ B(I,J)=A(I,J)\ NEXT J
3850      B(I,I+4)=1\ NEXT I
3860 REM      Perform row oriented operations to convert the left hand side of B
3870 REM      to the identity matrix. The inverse of A will then be on the right.
3880 FOR K=1 TO 4
3890      IF K=4 THEN 3960 ELSE M%=K
3900      REM      Find maximum element
3910      FOR I=K+1 TO 4\ IF ABS(B(I,K))>ABS(B(M%,K)) THEN M%=I

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3920 NEXT I
3930 IF M%=K GOTO 3960
3940 FOR J=K TO 8/B=B(K,J)\B(K,J)=B(M%,J)\B(M%,J)=B\ NEXT J
3950 REM Divide Row K
3960 FOR J=K+1 TO 8\B(K,J)=B(K,J)/B(K,K)\ NEXT J
3970 IF K=1 GOTO 4010
3980 FOR I=1 TO K-1\ FOR J=K+1 TO 8\B(I,J)=B(I,J)-B(I,K)*B(K,J)\ NEXT J
3990 NEXT I
4000 IF K=4 GOTO 4030
4010 FOR I=K+1 TO 4\ FOR J=K+1 TO 8\B(I,J)=B(I,J)-B(I,K)*B(K,J)\ NEXT J
4020 NEXT I
4030 NEXT K
4040 REM Retrieve inverse from the right side of Matrix B
4050 FOR I=1 TO 4\ FOR J=1 TO 4\B(I,J)=B(I,J+4)\ NEXT J\ NEXT I\ RETURN
4060 REM MAXIMUM STIFFENER MOMENT AND BENDING STRESS SUBROUTINE
4070 REM Calculate maximum positive and negative stiffener moments
4080 FOR I=1 TO 4
4090 IF M(I,1)<0 THEN MMAXNEG(I)=M(I,1) ELSE MMAXNEG(I)=0
4100 IF M(I,1)>0 THEN MMAXPOS(I)=M(I,1) ELSE MMAXPOS(I)=0
4110 FOR X=.5 TO LFT(I) STEP .5
4120 MX1=M(I,1)+(3*W(I,LC)*LFT(I)/500-(M(I,1)+M(I,2))/LFT(I))*X
4130 MX=MX1-3*W(I,LC)*X^2/500
4140 IF MX<MMAXNEG(I) THEN MMAXNEG(I)=MX
4150 IF MX>MMAXPOS(I) THEN MMAXPOS(I)=MX
4160 NEXT X\ NEXT I
4170 REM Calculate maximum bending stresses
4180 FOR I=1 TO 4\FBM(I,1,1)=MMAXPOS(I)*(DST(I)-Y1(I))/IE(I)
4190 FBM(I,2,1)=MMAXPOS(I)*Y1(I)/IE(I)
4200 FBM(I,3,1)=MMAXPOS(I)*(DST(I)+T(I)-Y1(I))/IE(I)
4210 FBM(I,1,2)=MMAXNEG(I)*Y1(I)/IE(I)
4220 FBM(I,2,2)=MMAXNEG(I)*(DST(I)-Y1(I))/IE(I)
4230 FBM(I,3,2)=MMAXNEG(I)*(DST(I)+T(I)-Y1(I))/IE(I)\ NEXT I\ RETURN
4240 REM ALLOWABLE BENDING STRESS SUBROUTINE
4250 IF LBRC(I)/12<LFT(I) THEN 4320
4260 IF ABS(MMAXNEG(I))>ABS(M(I,1)) AND ABS(MMAXNEG(I))>ABS(M(I,2)) THEN 4320
4270 IF MMAXPOS(I)>ABS(M(I,1)) AND MMAXPOS(I)>ABS(M(I,2)) THEN 4320
4280 IF ABS(M(I,1))<ABS(M(I,2)) THEN MRATIO=M(I,1)/M(I,2)\ GOTO 4300
4290 MRATIO=M(I,2)/M(I,1)
4300 CB=1.75+1.05*MRATIO+.3*MRATIO^2\ IF CB>2.3 THEN CB=2.3
4310 GOTO 4330
4320 CB=1
4330 IF SHP=3 GOTO 4590
4340 REM W and WT Shapes
4350 REM Positive Moments
4360 IF WELD*(I)<>'C' GOTO 4470
4370 IF FAC(I)/FYS>.16 GOTO 4390
4380 IF DST(I)/TW(I)>(640/SQR(FYS))*(1-3.74*FAC(I)/FYS) THEN 4470 ELSE 4400
4390 IF DST(I)/TW(I)>257/SQR(FYS) THEN 4470
4400 IF LBRC(I)>76/SQR(FYS) GOTO 4470
4410 IF LBRC(I)>20000*TF(I)*BF(I)/((DST(I)+T(I))*FYS) GOTO 4470
4420 IF BF(I)/((2*TF(I)))>95/SQR(FYS) GOTO 4470
4430 IF BF(I)/((2*TF(I)))>65/SQR(FYS) GOTO 4450
4440 FB(I,1,1)=.66*FYS\FB(I,2,1)=.66*FYS\FB(I,3,1)=.66*FYP\ GOTO 4560
4450 FB(I,1,1)=FYS*(.79-.002*BF(I)*SQR(FYS)/(2*TF(I)))\FB(I,2,1)=FB(I,1,1)
4460 FB(I,3,1)=FB(I,1,1)*FYP/FYS\ GOTO 4560
4470 FB(I,1,1)=.6*FYS\FB(I,3,1)=.6*FYP

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4480 IF BF(I)/(2*TF(I))>95/SQR(FYS) THEN FB(I,2,1)=.001\ GOTO 4560
4490 IF LBRC(I)<=76*BF(I)/SQR(FYS) THEN FB(I,2,1)=.6*FYS\ GOTO 4560
4500 IF LBRC(I)>SQR(510000*CB/FYS)*RT(I) GOTO 4530
4510 FB(I,2,1)=(2/3-FYS*(LBRC(I)/RT(I))^2/((.153E+07*CB))*FYS
4520 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS\ GOTO 4560
4530 FB(I,2,1)=170000*CB/(LBRC(I)/RT(I))^2
4540 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS
4550 REM Negative Moments
4560 FB(I,1,2)=.6*FYS\FB(I,2,2)=.6*FYS\FB(I,3,2)=.6*FYP\ GOTO 4660
4570 REM Channels
4580 REM Positive Moments
4590 FB(I,1,1)=.6*FYS\FB(I,3,1)=.6*FYP
4600 IF BF(I)/TF(I)>95/SQR(FYS) THEN FB(I,2,1)=.001\ GOTO 4650
4610 IF LBRC(I)<=76*BF(I)/SQR(FYS) THEN FB(I,2,1)=.6*FYS\ GOTO 4650
4620 FB(I,2,1)=12000*CB*(BF(I)*TF(I))/(LBRC(I)*(DST(I)+T(I)))
4630 IF FB(I,2,1)>.6*FYS THEN FB(I,2,1)=.6*FYS
4640 REM Negative Moments
4650 FB(I,1,2)=.6*FYS\FB(I,2,2)=.6*FYS\FB(I,3,2)=.6*FYP
4660 RETURN
4670 REM INTERACTION FORMULAS SUBROUTINE
4680 FE=PI^2*ES*IE(I)/(397.44*LFT(I)^2*AE(I))
4690 ON LCOND GOTO 4700,4730,4760
4700 FA=FA(I)\FBSCP=FB(I,2,1)\FBSCN=FB(I,2,2)\CFYS=.6*FYS\CFYP=.6*FYP
4710 FBSTP=FB(I,1,1)\FBSTN=FB(I,1,2)\FBPP=FB(I,3,1)\FBPN=FB(I,3,2)
4720 GOTO 4800
4730 FA=4*FA(I)/3\FBSCP=4*FB(I,2,1)/3\FBSCN=4*FB(I,2,2)/3\CFYS=.8*FYS
4740 FE=4*FE/3\CFYP=.8*FYP\FBSTP=4*FB(I,1,1)/3\FBSTN=4*FB(I,1,2)/3
4750 FBPP=4*FB(I,3,1)/3\FBPN=4*FB(I,3,2)/3\ GOTO 4800
4760 FA=5*FA(I)/3\FBSCP=5*FB(I,2,1)/3\ IF FBSCP>FYS THEN FBSCP=FYS
4770 CFYS=FYS\FBSCN=5*FB(I,2,2)/3\ IF FBSCN>FYS THEN FBSCN=FYS
4780 FE=23*FE/12\CFYP=FYP\FBSTP=5*FB(I,1,1)/3\ IF FBSTP>FYS THEN FBSTP=FYS
4790 FBPP=FYP\FBPN=FYP\FBSTN=5*FB(I,1,2)/3\ IF FBSTN>FYS THEN FBSTN=FYS
4800 IF FAC(I)<=0 GOTO 5010
4810 REM Simultaneous Axial Compression and Transverse Loading
4820 IF FAC(I)/FA>.15 GOTO 4870
4830 REM Negligible Axial Stress
4840 IF FAC(I)/FA+FBM(I,2,1)/FBSCP>1 THEN 5080
4850 IF FAC(I)/FA+ABS(FBM(I,2,2))/FBSCN>1 THEN 5080 ELSE 4970
4860 REM Significant Axial Stress
4870 IF FAC(I)/FA+.85*FBM(I,2,1)/((1-FAC(I)/FE)*FBSCP)>1 GOTO 5080
4880 IF FAC(I)/FA+.85*ABS(FBM(I,2,2))/((1-FAC(I)/FE)*FBSCN)>1 GOTO 5080
4890 IF M(I,1)<0 GOTO 4910
4900 IF FAC(I)/CFYS+M(I,1)*Y1(I)/(IE(I)*FBSCP)>1 THEN 5080 ELSE 4920
4910 IF FAC(I)/CFYS-M(I,1)*(DST(I)-Y1(I))/(IE(I)*FBSCN)>1 GOTO 5080
4920 IF M(I,2)<0 GOTO 4950
4930 IF FAC(I)/CFYS+M(I,2)*(DST(I)-Y1(I))/(IE(I)*FBSCN)>1 THEN 5080
4940 GOTO 4970
4950 IF FAC(I)/CFYS-M(I,2)*Y1(I)/(IE(I)*FBSCP)>1 GOTO 5080
4960 REM Check Maximum Plate Stress
4970 IF FYP>FYS GOTO 5090
4980 IF FAC(I)/CFYP+ABS(FBM(I,3,2))/FBPN>1 GOTO 5080
4990 IF FBM(I,3,1)>FBPP THEN 5080 ELSE 5090
5000 REM Simultaneous Axial Tension and Transverse Loading
5010 IF FAC(I)/CFYS+FBM(I,1,1)/FBSTP>1 GOTO 5080
5020 IF FAC(I)/CFYS+ABS(FBM(I,1,2))/FBSTN>1 GOTO 5080
5030 IF FBM(I,2,1)>FBSCP GOTO 5080

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5040 IF ABS(FBM(I,2,2))>FBSCN GOTO 5080
5050 REM      Check Maximum Plate Stress
5060 IF ABS(FAC(I))/CFYP+FBM(I,3,1)/FBPP>1 GOTO 5080
5070 IF ABS(FBM(I,3,2))>FBPN THEN 5080 ELSE 5090
5080 FLAG(I)=1
5090 RETURN
5100 REM      COMBINED STIFFENER AND ADJACENT EFFECTIVE PLATE DEFLECTION SUBROUTINE
5110 REM      Calculate Maximum Stiffener Deflection
5120 DMAX=0\ IF PD(I)<=0 GOTO 5220
5130 REM      Simultaneous axial compression and transverse loading
5140 FOR X=.5 TO LFT(I) STEP .5\T1=12*K1(I)*X\T2=12*K1(I)*LFT(I)
5150     TERM1=FNTAN(6*K1(I)*LFT(I))*SIN(T1)+72*K1(I)^2*X^2+COS(T1)-1
5160     DSXA=W(I,LC)*TERM1/(12*K1(I)^2*PD(I))-6*W(I,LC)*LFT(I)*X/PD(I)
5170     DSXB1=-1000*M(I,1)*(SIN(T1)/FNTAN(T2)-COS(T1)-X/LFT(I)+1)/PD(I)
5180     DSXB2=-1000*M(I,2)*(SIN(T1)/SIN(T2)-X/LFT(I))/PD(I)
5190     DSX=DSXA+DSXB1+DSXB2\ IF ABS(DSX)>DMAX THEN DMAX=ABS(DSX)
5200 NEXT X\ GOTO 5290
5210 REM      Simultaneous axial tension and transverse loading
5220 FOR X=.5 TO LFT(I) STEP .5
5230     TERM1=.072*W(I,LC)*X*(LFT(I)^3-2*LFT(I)*X^2+X^3)/(ES*IE(I))
5240     TERM2=24*M(I,1)*X*(LFT(I)-X)*(2*LFT(I)-X)/(LFT(I)*ES*IE(I))
5250     TERM3=24*M(I,2)*LFT(I)*X*(1-X^2/LFT(I)^2)/(ES*IE(I))
5260     DSX=TERM1+TERM2+TERM3\ IF ABS(DSX)>DMAX THEN DMAX=ABS(DSX)
5270 NEXT X
5280 REM      Compare Maximum Deflection to Allowable Deflection
5290 IF DMAX>LFT(I)*12/DSA(LCOND) THEN FLAG(I)=1
5300 RETURN
5310 REM      AISC 1.10.5.4 STIFFENER MOMENT OF INERTIA AND GROSS AREA REQUIREMENTS
5320 REM      Stiffener Moment of Inertia Requirement
5330 IW=IXS(I)+AST(I)*(DST(I)-YS(I)+T(I)/2)^2
5340 IF I=2 THEN LYT=LY(2)\LYB=LY(3)\ GOTO 5360
5350     LYT=LY(1)\LYB=LY(4)
5360 HWEB=12*LFT(I)-LYT-LYB\ IF IW<(HWEB/50)^4 GOTO 5450
5370 REM      Stiffener Gross Area Requirement
5380 ALPHA=SS(I)/HWEB\K2=4+(5.34/ALPHA^2)\CV=45000*K2/(FYP*(HWEB/T(I))^2)
5390 IF CV>.8 THEN CV=190*SQR(K2/FYP)/(HWEB/T(I))
5400 FVAVG=WG*LSPAN/(4000*HWEB*T(I))\FVALL=FYP*CV/2.89
5410 IF FVALL>.4*FYP THEN FVALL=.4*FYP
5420 BETA=2.4*FVAVG/FVALL
5430 AREQ=(1-CV)*(ALPHA-ALPHA^2/SQR(1+ALPHA^2))*FYP*HWEB*T(I)*BETA/(2*FYS)
5440 IF AST(I)<AREQ THEN 5450 ELSE 5460
5450 FLAG(I)=1
5460 RETURN

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## APPENDIX D

### DESIGN EXAMPLE

A rectangular section of horizontal ductwork is designed using the allowable stress design procedure detailed in Appendix B. The following computer output is generated by the programs listed in Appendix C. Both the pinned-end stiffener and rigid frame stiffener programs are used. The design inputs shown in the following computer printouts, including physical dimensions, material properties, design loads and design criteria, are identical to those used in a previous hand-calculated duct design. Results are tabulated and compared in Chapter VI.

## DUCTWORK STRUCTURAL DESIGN

WHAT IS THE DUCT SPAN (CLEAR DISTANCE BETWEEN SUPPORTS) IN FEET?  
? 47.5

INPUT THE WIDTHS OF SIDES 1,2,3 AND 4 IN FEET.  
(SIDE 1=TOP, SIDES 2 AND 4=SIDES, SIDE 3=BOTTOM)  
? 12,14,12,14

THE FOLLOWING INPUT IS USED TO CALCULATE THE ADJUSTED MAINTENANCE LIVE LOAD.

INPUT THE ANGLE BETWEEN THE TOP PLATE AND HORIZONTAL AND THE  
ANGLE BETWEEN THE BOTTOM PLATE AND HORIZONTAL, IN DEGREES.  
(MUST BE LESS THAN OR EQUAL TO 45 DEGREES)  
? 0,0

WHAT IS THE NOMINAL MAINTENANCE LIVE LOAD IN PSF?  
? 25

INPUT AN INITIAL ESTIMATION OF THE STIFFENER SPACING IN INCHES  
(USE INITIAL EST. OF 36 IN. IF NO BETTER VALUE IS AVAILABLE)  
? 48

THE FOLLOWING INPUT IS USED TO CALCULATE DESIGN WIND LOADS.

WHAT IS THE HEIGHT OF THE TOP OF THE DUCT ABOVE THE GROUND IN FT?  
? 55

WHAT IS MEAN HEIGHT OF THE DUCT SECTION ABOVE THE GROUND IN FT?  
(HEIGHT OF CENTERLINE OF THE DUCT SECTION ABOVE THE GROUND)  
? 48

WHAT IS THE BASIC WIND SPEED IN MILES PER HOUR?  
(FROM PDM OR ANSI A58.1-1982, FIGURE 1, TABLE 7 OR SECTION 6.5)  
? 80

HOW MANY MILES INLAND FROM A HURRICANE OCEAN LINE?  
(IF GREATER THAN 100 MILES ENTER 100)  
? 100

WHAT IS THE MINIMUM WIND LOADING, FROM PDM, IN PSF?  
(DEFAULT VALUE IS 10 PSF, PER ANSI 58.1-1982, SECTION 6.4.2.1)  
? 20

WIND EXPOSURE CATEGORY C OR D?  
(FROM ANSI 58.1-1982, SECTION 6.5.3, OR FROM PDM)  
? C

WILL THE DUCTWORK HAVE INSULATION AND LAGGING? (Y OR N)  
? Y

IS THE BOTTOM DUCT PANEL EXPOSED TO WIND FORCES? (Y OR N)  
? Y

THE FOLLOWING INPUT IS USED TO CALCULATE DESIGN SNOW LOADS.

WHAT IS THE GROUND SNOW LOAD IN PSF?  
(FROM PDM OR ANSI A58.1-1982, FIGURES 5,6, OR 7, TAB. 17, OR A7.2)  
? 20

IS THE POWER PLANT IN ALASKA? (Y OR N)  
? N

WHAT IS THE SNOW EXPOSURE FACTOR?  
(FROM ANSI A58.1-1982, TAB. 18; =0.8, 0.9, 1.0, 1.1, OR 1.2)  
? 1

IS THE DUCT FOR UNHEATED AIR OR FOR HEATED AIR/FLUE GAS? (U OR H)  
? H

THE FOLLOWING INPUT IS USED TO DETERMINE SEISMIC LOADING.

WHAT IS THE SEISMIC ZONE?  
(FROM PDM OR ANSI A58.1-1982, FIGURES 13 OR 14)  
? 2

INPUT AN INITIAL ESTIMATE OF PLATE THICKNESSES OF SIDES 1-4, IN.  
(USE INITIAL ESTIMATE OF .3125 IN. IN ABSENCE OF A BETTER VALUE)  
? .3125,.3125,.3125,.3125

INPUT DUCT LINING DEAD LOAD, PSF  
? 0

WHAT IS THE UNIT WEIGHT OF THE DUCT PLATE IN PCF?  
? 490

WHAT IS THE ASH LIVE LOAD ON THE BOTTOM PANEL IN PSF?  
? 170

WHAT IS THE ASH LATERAL LIVE LOAD COEFFICIENT?  
(USED TO DETERMINE ASH LIVE LOAD ON THE DUCT SIDE PANELS;  
SUGGESTED RANGE IS FROM .05 TO .10)  
? .1



THE FOLLOWING INPUT IS USED TO DETERMINE OPERATING AND EXCURSION LOADS

ENTER THE DESIGN OPERATING VACUUM FOR THIS DUCT SECTION (IN.W.G.)  
? 20

ENTER THE DESIGN OPERATING PRESSURE FOR THE DUCT SECTION (IN.W.G.)  
? 20

ENTER THE DESIGN EXCURSION VACUUM FOR THIS DUCT SECTION (IN.W.G.)  
? 43

ENTER THE DESIGN EXCURSION PRESSURE FOR THE DUCT SECTION (IN.W.G.)  
? 20

THE FOLLOWING INPUT IS USED IN THE DUCT PLATE DESIGN

WHAT IS THE MODULUS OF ELASTICITY OF THE PLATE IN KSI?  
? 29000

WHAT IS POISSON'S RATIO FOR THE PLATE?  
? .3

ENTER THE MAXIMUM ALLOWABLE PLATE DEFLECTION FOR NORMAL OPERATING CONDITIONS:  
ENTER XXX, WHERE MAX. ALLOW. DEFLECTION = PLATE SPAN/XXX  
(SUGGESTED VALUE FOR XXX IS 100)  
? 100

DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE PLATE DEFLECTION UNDER WIND OR SEISMIC FORCES? (Y OR N)  
? Y

ENTER THE MAXIMUM ALLOWABLE PLATE DEFLECTION UNDER WIND OR SEISMIC FORCES:  
ENTER XXX, WHERE MAX. ALLOW. DEFLECTION = PLATE SPAN/XXX  
? 75

DO YOU WANT TO SPECIFY A MAXIMUM PLATE DEFLECTION UNDER EXCURSION PRESSURE OR VACUUM CONDITIONS? (Y OR N)  
? N

ENTER THE PLATE YIELD STRESS IN KSI  
? 50

YOU NOW HAVE TWO OPTIONS, AS DESCRIBED BELOW:

1. UNDER OPTION 1, THIS PROGRAM WILL GENERATE A SET OF TABLES DISPLAYING MAXIMUM PLATE STRESSES AND DEFLECTIONS FOR VARIOUS STIFFENER SPACING AND PLATE THICKNESS COMBINATIONS. FROM THESE TABLES YOU WILL SELECT AN ACCEPTABLE PLATE THICKNESS AND STIFFENER SPACING FOR EACH OF THE FOUR SIDES OF THE DUCT. IT WILL TAKE APPROXIMATELY 50 TO 60 MINUTES FOR THE COMPUTER TO GENERATE THESE TABLES.

2. UNDER OPTION 2, YOU MUST ENTER TRIAL VALUES OF PLATE THICKNESS AND STIFFENER SPACING FOR EACH OF THE FOUR DUCT SIDES. MAXIMUM PLATE STRESSES AND DEFLECTIONS ARE THEN CALCULATED AND DISPLAYED. YOU ARE GIVEN THE OPPORTUNITY TO CHANGE PLATE THICKNESSES AND/OR STIFFENER SPACINGS AS REQUIRED. OPTION 2 IS FASTER THAN OPTION 1, BUT THE MOST EFFICIENT DESIGN MAY BE OVERLOOKED USING OPTION 2.

DO YOU WISH TO SELECT OPTION 1 OR OPTION 2? (ENTER 1 OR 2)

? 1

FOR EACH PLATE THICKNESS VS. STIFFENER SPACING COMBINATION IN EACH OF THE FOLLOWING FOUR TABLES THE FOLLOWING INFORMATION IS TABULATED:

AA.AA	AA.AA = MAXIMUM DUCT PLATE STRESS UNDER NORMAL OPERATING CONDITIONS
B.BB	B.BB = MAXIMUM PLATE DEFLECTION UNDER NORMAL OPERATING CONDITIONS
CC.CC	CC.CC = MAXIMUM PLATE STRESS UNDER WIND OR SEISMIC FORCES
D.DD	D.DD = MAXIMUM PLATE DEFLECTION UNDER WIND OR SEISMIC FORCES
EE.EE	EE.EE = MAXIMUM PLATE STRESS FOR PRESSURE EXCURSION CONDITIONS
F.FF	F.FF = MAXIMUM PLATE DEFLECTION FOR PRESSURE EXCURSION CONDITIONS

ADDITIONAL NOTES:

- 1) STRESSES ARE IN KSI, DEFLECTIONS ARE IN INCHES.
- 2) AN ASTERISK (\*) FOLLOWING A NUMBER INDICATES THAT THE STRESS INTERACTION REQUIREMENT IS NOT SATISFIED FOR THIS LOAD CONDITION, OR THE DEFLECTION EXCEEDS THE ALLOWABLE.
- 3) \*\*\*\*\* INDICATES THAT THE LOAD/DIMENSIONS COMBINATION IS OUTSIDE THE RANGE OF TIMOSHENKO'S METHOD, OR INVOLVES CALCULATIONS WITH REAL NUMBERS OF MAGNITUDES EXCEEDING THE REPRESENTATION CAPABILITY OF PRO BASIC ON THE DEC 350 COMPUTER.

## STRESSES AND DEFLECTIONS FOR SIDE 1 DUCT PLATE (INTERIOR PANELS)

		PLATE THICKNESS (INCHES)						
STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	3/16	1/4	5/16	3/8	7/16	1/2	
24		6.71	*****	*****	*****	*****	*****	
	0.24	0.04	*****	*****	*****	*****	*****	
		6.82	*****	*****	*****	*****	*****	
	0.32	0.04	*****	*****	*****	*****	*****	
		13.27	7.65	*****	*****	*****	*****	
	N/A	0.07	0.03	*****	*****	*****	*****	
30		10.09	5.91	*****	*****	*****	*****	
	0.30	0.08	0.04	*****	*****	*****	*****	
		10.25	6.01	*****	*****	*****	*****	
	0.40	0.09	0.04	*****	*****	*****	*****	
		18.56	11.82	7.65	*****	*****	*****	
	N/A	0.14	0.08	0.04	*****	*****	*****	
36		13.14	8.40	5.44	*****	*****	*****	
	0.36	0.14	0.08	0.04	*****	*****	*****	
		13.32	8.53	5.53	*****	*****	*****	
	0.48	0.14	0.08	0.04	*****	*****	*****	
		22.78	16.05	10.95	7.65	*****	*****	
	N/A	0.21	0.14	0.08	0.05	*****	*****	
42		15.66	10.91	7.38	5.14	*****	*****	
	0.42	0.20	0.13	0.08	0.05	*****	*****	
		15.86	11.07	7.50	5.23	*****	*****	
	0.56	0.20	0.13	0.08	0.05	*****	*****	
		26.31	19.70	14.40	10.38	7.65	5.86	
	N/A	0.28	0.21	0.14	0.09	0.06	0.04	
48		17.80	13.14	9.42	6.71	4.93	*****	
	0.48	0.26	0.19	0.12	0.08	0.05	*****	
		18.02	13.32	9.57	6.82	5.02	*****	
	0.64	0.27	0.19	0.13	0.08	0.05	*****	
		29.46	22.78	17.59	13.27	9.97	7.65	
	N/A	0.36	0.28	0.21	0.15	0.10	0.07	
54		19.73	15.07	11.38	8.40	6.25	4.77	
	0.54	0.32	0.25	0.18	0.12	0.08	0.05	
		19.96	15.26	11.55	8.53	6.35	4.86	
	0.72	0.33	0.25	0.18	0.12	0.08	0.05	
		32.38	25.47	20.36	16.05	12.44	9.67	
	N/A	0.43	0.36	0.28	0.21	0.15	0.11	
60		21.51	16.76	13.14	10.09	7.67	5.91	
	0.60	0.39	0.31	0.24	0.17	0.12	0.08	
		21.77	16.97	13.32	10.25	7.79	6.01	
	0.80	0.39	0.31	0.24	0.17	0.12	0.08	
		35.14	27.92	22.78	18.56	14.88	11.82	
	N/A	0.51	0.43	0.35	0.28	0.21	0.16	

## STRESSES AND DEFLECTIONS FOR SIDE 1 DUCT PLATE (INTERIOR PANELS)

STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	PLATE THICKNESS (INCHES)					
		3/16	1/4	5/16	3/8	7/16	1/2
66		23.20	18.30	14.71	11.69	9.13	7.13
	0.66	0.45	0.37	0.30	0.23	0.16	0.12
		23.47	18.52	14.90	11.86	9.27	7.24
	0.88	0.45	0.37	0.30	0.23	0.17	0.12
		37.77	30.21	24.96	20.79	17.16	13.98
72	N/A	0.58	0.50	0.43	0.35	0.28	0.22
		24.81	19.73	16.11	13.14	10.56	8.40
	0.72	0.51	0.43	0.36	0.29	0.22	0.16
		25.10	19.96	16.31	13.32	10.72	8.53
	0.96	0.51	0.44	0.36	0.29	0.22	0.16
78		40.30	32.38	26.97	22.78	19.22	16.05
	N/A	0.66	0.57	0.50	0.42	0.35	0.28
		26.36	21.08	17.39	14.46	11.91	9.67
	0.78	0.57	0.49	0.42	0.35	0.27	0.21
		26.67	21.32	17.61	14.65	12.08	9.82
84	1.04	0.58	0.50	0.42	0.35	0.28	0.21
		42.74	34.46	28.86	24.61	21.08	17.36
	N/A	0.74	0.65	0.57	0.50	0.42	0.35
		27.86	22.37	18.59	15.66	13.14	10.91
	0.84	0.64	0.56	0.48	0.41	0.33	0.26
90		28.19	22.63	18.82	15.86	13.32	11.07
	1.12	0.64	0.56	0.48	0.41	0.34	0.27
		45.11	36.47	30.66	26.31	22.78	19.70
	N/A	0.82	0.73	0.64	0.57	0.50	0.42
		29.32	23.61	19.73	16.76	14.28	12.07
96	0.90	0.71	0.62	0.54	0.47	0.39	0.32
		29.66	23.88	19.96	16.97	14.47	12.24
	1.20	0.71	0.62	0.54	0.47	0.40	0.32
		47.41	38.41	32.38	27.92	24.36	21.30
	N/A	0.91	0.80	0.72	0.64	0.57	0.49
		30.73	24.81	20.81	17.80	15.32	13.14
	0.96	0.77	0.68	0.60	0.53	0.45	0.38
		31.09	25.10	21.06	18.02	15.52	13.32
	1.28	0.78	0.68	0.61	0.53	0.46	0.38
		49.65	40.30	34.06	29.46	25.84	22.78
	N/A	0.99	0.88	0.79	0.71	0.64	0.57

## STRESSES AND DEFLECTIONS FOR SIDE 2 DUCT PLATE (INTERIOR PANELS)

		PLATE THICKNESS (INCHES)						
STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	3/16	1/4	5/16	3/8	7/16	1/2	
24		6.95	*****	*****	*****	*****	*****	
	0.24	0.04	*****	*****	*****	*****	*****	
		7.41	4.17	*****	*****	*****	*****	
	0.32	0.04	0.02	*****	*****	*****	*****	
		12.59	7.24	*****	*****	*****	*****	
	N/A	0.07	0.03	*****	*****	*****	*****	
30		10.42	6.12	*****	*****	*****	*****	
	0.30	0.09	0.04	*****	*****	*****	*****	
		11.05	6.53	4.17	*****	*****	*****	
	0.40	0.09	0.04	0.02	*****	*****	*****	
		17.73	11.20	7.24	*****	*****	*****	
	N/A	0.14	0.07	0.04	*****	*****	*****	
36		13.53	8.69	5.64	*****	*****	*****	
	0.36	0.15	0.08	0.04	*****	*****	*****	
		14.25	9.24	6.02	4.17	*****	*****	
	0.48	0.15	0.09	0.05	0.03	*****	*****	
		21.85	15.29	10.37	7.24	*****	*****	
	N/A	0.21	0.13	0.08	0.05	*****	*****	
42		16.08	11.26	7.64	5.33	*****	*****	
	0.42	0.21	0.14	0.08	0.05	*****	*****	
		16.88	11.91	8.13	5.69	4.17	*****	
	0.56	0.21	0.14	0.09	0.05	0.03	*****	
		25.28	18.85	13.69	9.82	7.24	5.53	
	N/A	0.28	0.20	0.14	0.09	0.06	0.04	
48		18.27	13.53	9.74	6.95	5.11	*****	
	0.48	0.27	0.19	0.13	0.08	0.05	*****	
		19.14	14.25	10.34	7.41	5.45	4.17	
	0.64	0.28	0.20	0.13	0.09	0.06	0.04	
		28.33	21.85	16.79	12.59	9.44	7.24	
	N/A	0.35	0.28	0.20	0.14	0.09	0.06	
54		20.23	15.49	11.74	8.69	6.47	4.95	
	0.54	0.33	0.26	0.18	0.12	0.08	0.06	
		21.18	16.27	12.41	9.24	6.90	5.28	
	0.72	0.34	0.26	0.19	0.13	0.09	0.06	
		31.16	24.47	19.49	15.29	11.80	9.15	
	N/A	0.42	0.35	0.27	0.20	0.14	0.10	
60		22.06	17.21	13.53	10.42	7.94	6.12	
	0.60	0.39	0.32	0.24	0.17	0.12	0.08	
		23.07	18.05	14.25	11.05	8.45	6.53	
	0.80	0.40	0.33	0.25	0.18	0.13	0.09	
		33.82	26.84	21.85	17.73	14.16	11.20	
	N/A	0.50	0.42	0.34	0.27	0.20	0.15	

## STRESSES AND DEFLECTIONS FOR SIDE 2 DUCT PLATE (INTERIOR PANELS)

		PLATE THICKNESS (INCHES)						
STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	3/16	1/4	5/16	3/8	7/16	1/2	
66		23.78	18.78	15.12	12.05	9.44	7.38	
	0.66	0.45	0.38	0.30	0.23	0.17	0.12	
		24.87	19.67	15.89	12.73	10.02	7.86	
	0.88	0.46	0.39	0.31	0.24	0.18	0.13	
		36.36	29.06	23.97	19.90	16.37	13.28	
	N/A	0.57	0.49	0.42	0.34	0.27	0.21	
72		25.43	20.23	16.54	13.53	10.90	8.69	
	0.72	0.52	0.44	0.36	0.29	0.22	0.16	
		26.59	21.18	17.36	14.25	11.54	9.24	
	0.96	0.53	0.45	0.38	0.30	0.23	0.17	
		38.80	31.16	25.91	21.85	18.38	15.29	
	N/A	0.65	0.56	0.49	0.41	0.34	0.27	
78		27.02	21.61	17.85	14.87	12.27	10.00	
	0.78	0.58	0.50	0.43	0.35	0.28	0.21	
		28.24	22.61	18.71	15.63	12.96	10.60	
	1.04	0.60	0.51	0.44	0.37	0.29	0.23	
		41.15	33.16	27.74	23.63	20.19	17.15	
	N/A	0.73	0.64	0.56	0.48	0.41	0.34	
84		28.55	22.93	19.07	16.08	13.53	11.26	
	0.84	0.65	0.56	0.49	0.41	0.34	0.27	
		29.84	23.98	19.98	16.88	14.25	11.91	
	1.12	0.66	0.58	0.50	0.43	0.35	0.28	
		43.43	35.10	29.48	25.28	21.85	18.85	
	N/A	0.81	0.71	0.63	0.56	0.48	0.41	
90		30.04	24.20	20.23	17.21	14.68	12.44	
	0.90	0.72	0.63	0.55	0.47	0.40	0.33	
		31.39	25.31	21.18	18.05	15.44	13.13	
	1.20	0.73	0.64	0.56	0.49	0.42	0.34	
		45.65	36.98	31.16	26.84	23.38	20.41	
	N/A	0.89	0.79	0.70	0.63	0.55	0.48	
96		31.49	25.43	21.34	18.27	15.75	13.53	
	0.96	0.78	0.69	0.61	0.54	0.46	0.39	
		32.90	26.59	22.33	19.14	16.53	14.25	
	1.28	0.80	0.71	0.63	0.55	0.48	0.40	
		47.81	38.80	32.77	28.33	24.82	21.85	
	N/A	0.97	0.86	0.78	0.70	0.62	0.55	

## STRESSES AND DEFLECTIONS FOR SIDE 3 DUCT PLATE (INTERIOR PANELS)

STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	PLATE THICKNESS (INCHES)					
		3/16	1/4	5/16	3/8	7/16	1/2
24		15.85	9.28	*****	*****	*****	*****
	0.24	0.09	0.04	*****	*****	*****	*****
		15.85	9.28	*****	*****	*****	*****
	0.32	0.09	0.04	*****	*****	*****	*****
	N/A	15.85	9.28	*****	*****	*****	*****
30		21.69	14.20	9.28	6.45	*****	*****
	0.30	0.16	0.09	0.05	0.03	*****	*****
		21.69	14.20	9.28	6.45	*****	*****
	0.40	0.16	0.09	0.05	0.03	*****	*****
	N/A	21.69	14.20	9.28	6.45	*****	*****
36		26.31	18.95	13.20	9.28	6.81	*****
	0.36	0.23	0.16	0.10	0.06	0.04	*****
		26.31	18.95	13.20	9.28	6.81	*****
	0.48	0.23	0.16	0.10	0.06	0.04	*****
	N/A	26.31	18.95	13.20	9.28	6.81	*****
42		30.22	22.94	17.13	12.53	9.28	7.10
	0.42	0.31	0.24	0.17	0.11	0.07	0.05
		30.22	22.94	17.13	12.53	9.28	7.10
	0.56	0.31	0.24	0.17	0.11	0.07	0.05
	N/A	30.22	22.94	17.13	12.53	9.28	7.10
48		33.75	26.31	20.64	15.85	12.05	9.28
	0.48	0.39	0.31	0.24	0.17	0.12	0.08
		33.75	26.31	20.64	15.85	12.05	9.28
	0.64	0.39	0.31	0.24	0.17	0.12	0.08
	N/A	33.75	26.31	20.64	15.85	12.05	9.28
54		37.04	29.29	23.65	18.95	14.92	11.69
	0.54	0.46	0.39	0.31	0.24	0.18	0.13
		37.04	29.29	23.65	18.95	14.92	11.69
	0.72	0.46	0.39	0.31	0.24	0.18	0.13
	N/A	37.04	29.29	23.65	18.95	14.92	11.69
60		40.16	32.02	26.31	21.69	17.66	14.20
	0.60	0.54	0.46	0.39	0.32	0.25	0.18
		40.16	32.02	26.31	21.69	17.66	14.20
	0.80	0.54	0.46	0.39	0.32	0.25	0.18
	N/A	40.16	32.02	26.31	21.69	17.66	14.20

## STRESSES AND DEFLECTIONS FOR SIDE 3 DUCT PLATE (INTERIOR PANELS)

		PLATE THICKNESS (INCHES)						
STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	3/16	1/4	5/16	3/8	7/16	1/2	
66		43.13	34.59	28.71	24.12	20.17	16.66	
	0.66	0.63	0.54	0.47	0.39	0.32	0.25	
		43.13	34.59	28.71	24.12	20.17	16.66	
	0.88	0.63	0.54	0.47	0.39	0.32	0.25	
	N/A	43.13	34.59	28.71	24.12	20.17	16.66	
72		46.00	37.04	30.95	26.31	22.41	18.95	
	0.72	0.71	0.62	0.54	0.47	0.39	0.32	
		46.00	37.04	30.95	26.31	22.41	18.95	
	0.96	0.71	0.62	0.54	0.47	0.39	0.32	
	N/A	46.00	37.04	30.95	26.31	22.41	18.95	
78		48.76	39.39	33.07	28.33	24.44	21.04	
	0.78	0.79*	0.70	0.62	0.54	0.47	0.40	
		48.76	39.39	33.07	28.33	24.44	21.04	
	1.04	0.79	0.70	0.62	0.54	0.47	0.40	
	N/A	48.76	39.39	33.07	28.33	24.44	21.04	
84		51.45	41.66	35.09	30.22	26.31	22.94	
	0.84	0.88*	0.78	0.70	0.62	0.55	0.47	
		51.45	41.66	35.09	30.22	26.31	22.94	
	1.12	0.88	0.78	0.70	0.62	0.55	0.47	
	N/A	51.45	41.66	35.09	30.22	26.31	22.94	
90		54.06	43.86	37.04	32.02	28.05	24.69	
	0.90	0.97*	0.86	0.77	0.70	0.62	0.55	
		54.06	43.86	37.04	32.02	28.05	24.69	
	1.20	0.97	0.86	0.77	0.70	0.62	0.55	
	N/A	54.06	43.86	37.04	32.02	28.05	24.69	
96		56.60	46.00	38.93	33.75	29.69	26.31	
	0.96	1.06*	0.94	0.85	0.77	0.70	0.62	
		56.60	46.00	38.93	33.75	29.69	26.31	
	1.28	1.06	0.94	0.85	0.77	0.70	0.62	
	N/A	56.60	46.00	38.93	33.75	29.69	26.31	



## STRESSES AND DEFLECTIONS FOR SIDE 4 DUCT PLATE (INTERIOR PANELS)

STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	PLATE THICKNESS (INCHES)					
		3/16	1/4	5/16	3/8	7/16	1/2
24		6.95	*****	*****	*****	*****	*****
	0.24	0.04	*****	*****	*****	*****	*****
		7.41	4.17	*****	*****	*****	*****
	0.32	0.04	0.02	*****	*****	*****	*****
	N/A	12.59	7.24	*****	*****	*****	*****
30		0.07	0.03	*****	*****	*****	*****
		10.42	6.12	*****	*****	*****	*****
	0.30	0.09	0.04	*****	*****	*****	*****
		11.05	6.53	4.17	*****	*****	*****
	0.40	0.09	0.04	0.02	*****	*****	*****
36		17.73	11.20	7.24	*****	*****	*****
	N/A	0.14	0.07	0.04	*****	*****	*****
		13.53	8.69	5.64	*****	*****	*****
	0.36	0.15	0.08	0.04	*****	*****	*****
		14.25	9.24	6.02	4.17	*****	*****
42		0.15	0.09	0.05	0.03	*****	*****
	0.48	21.85	15.29	10.37	7.24	*****	*****
	N/A	0.21	0.13	0.08	0.05	*****	*****
		16.08	11.26	7.64	5.33	*****	*****
	0.42	0.21	0.14	0.08	0.05	*****	*****
48		16.88	11.91	8.13	5.69	4.17	*****
	0.56	0.21	0.14	0.09	0.05	0.03	*****
		25.28	18.85	13.69	9.82	7.24	5.53
	N/A	0.28	0.20	0.14	0.09	0.06	0.04
		18.27	13.53	9.74	6.95	5.11	*****
54		0.27	0.19	0.13	0.08	0.05	*****
	0.48	19.14	14.25	10.34	7.41	5.45	4.17
		0.28	0.20	0.13	0.09	0.06	0.04
	0.64	28.33	21.85	16.79	12.59	9.44	7.24
	N/A	0.35	0.28	0.20	0.14	0.09	0.06
60		20.23	15.49	11.74	8.69	6.47	4.35
	0.54	0.33	0.26	0.18	0.12	0.08	0.06
		21.18	16.27	12.41	9.24	6.90	5.28
	0.72	0.34	0.26	0.19	0.13	0.09	0.06
		31.16	24.47	19.49	15.29	11.80	9.15
60		0.42	0.35	0.27	0.20	0.14	0.10
		22.06	17.21	13.53	10.42	7.94	6.12
	0.60	0.39	0.32	0.24	0.17	0.12	0.08
		23.07	18.05	14.25	11.05	8.45	6.53
	0.80	0.40	0.33	0.25	0.18	0.13	0.09
60		33.82	26.84	21.85	17.73	14.16	11.20
	N/A	0.50	0.42	0.34	0.27	0.20	0.15

## STRESSES AND DEFLECTIONS FOR SIDE 4 DUCT PLATE (INTERIOR PANELS)

		PLATE THICKNESS (INCHES)						
STIFFEN. SPACING (INCHES)	ALLOW. DEFLECT. (INCHES)	3/16	1/4	5/16	3/8	7/16	1/2	
66		23.78	18.78	15.12	12.05	9.44	7.38	
	0.66	0.45	0.38	0.30	0.23	0.17	0.12	
		24.87	19.67	15.89	12.73	10.02	7.86	
	0.88	0.46	0.39	0.31	0.24	0.18	0.13	
		36.36	29.06	23.97	19.90	16.37	13.28	
	N/A	0.57	0.49	0.42	0.34	0.27	0.21	
72		25.43	20.23	16.54	13.53	10.90	8.69	
	0.72	0.52	0.44	0.36	0.29	0.22	0.16	
		26.59	21.18	17.36	14.25	11.54	9.24	
	0.96	0.53	0.45	0.38	0.30	0.23	0.17	
		38.80	31.16	25.91	21.85	18.38	15.29	
	N/A	0.65	0.56	0.49	0.41	0.34	0.27	
78		27.02	21.61	17.85	14.87	12.27	10.00	
	0.78	0.58	0.50	0.43	0.35	0.28	0.21	
		28.24	22.61	18.71	15.63	12.96	10.60	
	1.04	0.60	0.51	0.44	0.37	0.29	0.23	
		41.15	33.16	27.74	23.63	20.19	17.15	
	N/A	0.73	0.64	0.56	0.48	0.41	0.34	
84		28.55	22.93	19.07	16.08	13.53	11.26	
	0.84	0.65	0.56	0.49	0.41	0.34	0.27	
		29.84	23.98	19.98	16.88	14.25	11.91	
	1.12	0.66	0.58	0.50	0.43	0.35	0.28	
		43.43	35.10	29.48	25.28	21.85	18.85	
	N/A	0.81	0.71	0.63	0.56	0.48	0.41	
90		30.04	24.20	20.23	17.21	14.68	12.44	
	0.90	0.72	0.63	0.55	0.47	0.40	0.33	
		31.39	25.31	21.18	18.05	15.44	13.13	
	1.20	0.73	0.64	0.56	0.49	0.42	0.34	
		45.65	36.98	31.16	26.84	23.38	20.41	
	N/A	0.89	0.79	0.70	0.63	0.55	0.48	
96		31.49	25.43	21.34	18.27	15.75	13.53	
	0.96	0.78	0.69	0.61	0.54	0.46	0.39	
		32.90	26.59	22.33	19.14	16.53	14.25	
	1.28	0.80	0.71	0.63	0.55	0.48	0.40	
		47.81	38.80	32.77	28.33	24.82	21.85	
	N/A	0.97	0.86	0.78	0.70	0.62	0.55	

FROM THE PRECEDING TABLES SELECT THE STIFFENER SPACING AND PLATE THICKNESS FOR EACH SIDE OF THE DUCT. IF STIFFENERS WITH RIGID (MOMENT-RESISTING) CONNECTIONS AT THE DUCT CORNERS ARE TO BE USED, THE STIFFENER SPACINGS SELECTED FOR EACH SIDE OF THE DUCT MUST BE EQUAL. IF PINNED (NON MOMENT-RESISTING) CONNECTIONS AT THE DUCT CORNERS ARE TO BE USED, THE STIFFENER SPACINGS FOR SEPARATE SIDES OF THE DUCT MAY BE DIFFERENT. HOWEVER, ALL STIFFENER SPACINGS CHOSEN SHOULD BE EVEN MULTIPLES OF THE MINIMUM STIFFENER SPACING SELECTED. IN EITHER CASE, PLATE THICKNESSES MAY VARY FROM SIDE TO SIDE.

ENTER THE PLATE THICKNESS (INCHES) AND STIFFENER SPACING (INCHES) FOR SIDE 1  
? .25,60

ENTER THE PLATE THICKNESS (INCHES) AND STIFFENER SPACING (INCHES) FOR SIDE 2  
? .25,60

ENTER THE PLATE THICKNESS (INCHES) AND STIFFENER SPACING (INCHES) FOR SIDE 3  
? .25,60

ENTER THE PLATE THICKNESS (INCHES) AND STIFFENER SPACING (INCHES) FOR SIDE 4  
? .25,60

SHALL A CORROSION ALLOWANCE BE ADDED TO THE PLATE THICKNESS ON EACH SIDE OF THE DUCT? (Y OR N)  
? Y

ENTER THE CORROSION ALLOWANCE IN DECIMALS OF AN INCH  
? .0625

NOTE: THE ADDITIONAL PLATE THICKNESS DUE TO THE CORROSION ALLOWANCE IS NOT CONSIDERED IN ANY STRUCTURAL CALCULATIONS, EXCEPT THAT THE PLATE DEAD LOAD IS INCREASED AS APPROPRIATE.

STRESSES AND DEFLECTIONS BASED ON THE ACTUAL DIMENSIONS SELECTED  
(INTERIOR PANELS - NONLINEAR THEORY)

	SIDE 1	SIDE 2	SIDE 3	SIDE 4
PLATE THICKNESS (INCHES)	.3125	.3125	.3125	.3125
STIFFENER SPACING (INCHES)	60	60	60	60
MAXIMUM STRESSES (KSI)				
NO WIND OR SEISMIC FORCES	16.76	17.21	32.02	17.21
WIND OR SEISMIC FORCES	16.93	17.99	32.02	17.99
EXCURSION CONDITIONS	27.92	26.84	32.02	26.84
MAXIMUM DEFLECTIONS (INCHES)				
NO WIND OR SEISMIC FORCES	0.31	0.32	0.46	0.32
WIND OR SEISMIC FORCES	0.31	0.33	0.46	0.33
EXCURSION CONDITIONS	0.43	0.42	0.46	0.42

- NOTES: 1) AN ASTERISK (\*) FOLLOWING A NUMBER INDICATES THAT THE STRESS INTER-ACTION REQUIREMENT IS NOT SATISFIED FOR THIS LOAD CONDITION, OR THE DEFLECTION EXCEEDS THE ALLOWABLE.
- 2) \*\*\*\*\* INDICATES THAT THE LOAD/DIMENSIONS COMBINATION IS OUTSIDE THE RANGE OF TIMOSHENKO'S METHOD OR INVOLVES CALCULATIONS WITH REAL NUMBERS OF MAGNITUDES EXCEEDING THE REPRESENTATION CAPABILITY OF PRO BASIC ON THE DEC 350 COMPUTER.
- 3) THE PLATE THICKNESSES SHOWN IN THE ABOVE TABLE INCLUDE THE CORROSION ALLOWANCE. STRESSES AND DEFLECTIONS SHOWN ABOVE ARE CALCULATED IGNORING THE ADDITIONAL PLATE THICKNESS DUE TO THE CORROSION ALLOWANCE, EXCEPT THAT THE ADDITIONAL WEIGHT OF THE PLATE IS CONSIDERED.

DO YOU WISH TO CHANGE A STIFFENER SPACING AND/OR PLATE THICKNESS PREVIOUSLY SELECTED? (Y OR N)  
? N

## MAXIMUM ALLOWABLE STIFFENER SPACINGS FOR DUCT END PANELS (LINEAR THEORY)

	SIDE 1	SIDE 2	SIDE 3	SIDE 4
PLATE THICKNESS (INCHES)	.3125	.3125	.3125	.3125
MAXIMUM STIFFENER SPACING BASED ON PLATE STRESS (INCHES)	50	52	40	52
MAXIMUM STIFFENER SPACING BASED ON DEFLECTION (INCHES)	45	45	34	45
MAXIMUM ALLOWABLE END PANEL STIFFENER SPACING (INCHES)	45	45	34	45

- NOTE: 1) THE MAXIMUM ALLOWABLE STIFFENER SPACINGS SHOWN ABOVE ARE BASED ON LINEAR THEORY. THE END PANELS ARE CONSIDERED TO BE SIMPLY SUPPORTED ALONG ONE STIFFENER AND FIXED ALONG THE OTHER. THE STIFFENERS ARE ASSUMED TO PROVIDE NO RESTRAINT IN THE PLANE OF THE PLATE.
- 2) THE PLATE THICKNESSES SHOWN ABOVE INCLUDE THE CORROSION ALLOWANCE PREVIOUSLY SPECIFIED.

## TRANSVERSE STIFFENER DESIGN

YOU MAY ELECT TO DESIGN THE TRANSVERSE STIFFENERS AS PINNED-END BEAM COLUMNS,  
OR AS A RIGID FRAME ENCIRCLING THE DUCT. IF YOU WISH TO EXECUTE THE PINNED-END  
STIFFENER DESIGN PROGRAM ENTER P. IF YOU WISH TO EXECUTE THE RIGID FRAME  
STIFFENER DESIGN PROGRAM ENTER R.  
? P

ENTER THE STIFFENER YIELD STRESS IN KSI  
? 50

ENTER THE MODULUS OF ELASTICITY OF THE STIFFENERS IN KSI  
? 29000

ENTER THE UNIT WEIGHT OF THE STIFFENERS IN PCF  
? 490

ENTER THE MAXIMUM ALLOWABLE STIFFENER DEFLECTION FOR NORMAL OPERATING CONDITIONS  
ENTER XXX, WHERE MAXIMUM ALLOWABLE DEFLECTION = STIFFENER SPAN/XXX  
(SUGGESTED VALUE FOR XXX IS 240)  
? 240

DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE STIFFENER DEFLECTION UNDER WIND OR  
SEISMIC FORCES? (Y OR N)  
? Y

ENTER THE MAXIMUM ALLOWABLE STIFFENER DEFLECTION UNDER WIND OR SEISMIC FORCES;  
ENTER XXX, WHERE MAXIMUM ALLOWABLE DEFLECTION = STIFFENER SPAN/XXX  
? 180

DO YOU WANT TO SPECIFY A MAXIMUM ALLOWABLE STIFFENER DEFLECTION UNDER EXCURSION  
CONDITIONS? (Y OR N)  
? N

ENTER THE APPROXIMATE WEIGHT OF INTERNAL BRACING IN THE DUCT SPAN IN POUNDS  
? 0

ENTER THE WEIGHT OF THE DUCT INSULATION AND LAGGING IN PSF  
? 7

WHAT SHAPE STIFFENERS DO YOU WISH TO USE? (W = W SHAPE, WT = STRUCTURAL TEE,  
C = CHANNEL)  
? WT

SMALLER STIFFENER SECTIONS MAY RESULT IF THE STIFFENERS ARE CONNECTED TO THE  
DUCT PLATE WITH CONTINUOUS WELDS.

WILL THE STIFFENERS ON SIDE 1 BE CONTINUOUSLY OR INTERMITTENTLY WELDED TO THE  
DUCT PLATE? (I = INTERMITTENT WELDS, C = CONTINUOUS WELD)  
? I

WILL THE STIFFENERS ON SIDE 2 BE CONTINUOUSLY OR INTERMITTENTLY WELDED TO THE  
DUCT PLATE? (I = INTERMITTENT WELDS, C = CONTINUOUS WELD)  
? I

WILL THE STIFFENERS ON SIDE 3 BE CONTINUOUSLY OR INTERMITTENTLY WELDED TO THE  
DUCT PLATE? (I = INTERMITTENT WELDS, C = CONTINUOUS WELD)  
? I

WILL THE STIFFENERS ON SIDE 4 BE CONTINUOUSLY OR INTERMITTENTLY WELDED TO THE  
DUCT PLATE? (I = INTERMITTENT WELDS, C = CONTINUOUS WELD)  
? I

SMALLER STIFFENER SECTIONS MAY RESULT IF THE EXTERIOR FLANGES (FLANGES NOT IN CONTACT WITH DUCT PLATE) ARE BRACED AGAINST TWIST OR LATERAL DISPLACEMENT. SUCH BRACING MAY BE PROVIDED BY WELDING STRAPS OR BARS PARALLEL TO THE LONGITUDINAL DIRECTION OF THE DUCT TO THE EXTERIOR FLANGE OF EACH TRANSVERSE STIFFENER.

WILL INTERMEDIATE BRACING AGAINST TWIST OR LATERAL DISPLACEMENT OF THE EXTERIOR STIFFENER FLANGES ON SIDE 1 BE PROVIDED? (Y OR N)  
? N

WILL INTERMEDIATE BRACING AGAINST TWIST OR LATERAL DISPLACEMENT OF THE EXTERIOR STIFFENER FLANGES ON SIDE 2 BE PROVIDED? (Y OR N)  
? N

WILL INTERMEDIATE BRACING AGAINST TWIST OR LATERAL DISPLACEMENT OF THE EXTERIOR STIFFENER FLANGES ON SIDE 3 BE PROVIDED? (Y OR N)  
? N

WILL INTERMEDIATE BRACING AGAINST TWIST OR LATERAL DISPLACEMENT OF THE EXTERIOR STIFFENER FLANGES ON SIDE 4 BE PROVIDED? (Y OR N)  
? N



## PINNED-END STIFFENER DESIGN

ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS  
(REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED TO HAVE THE  
SAME NOMINAL DEPTH)

? 6

## PINNED-END STIFFENERS

	SIDE 1	SIDE 2	SIDE 3	SIDE 4
STIFFENER SPACING (INCHES)	60	60	60	60
STIFFENER SECTION	WT6X13	WT6X17.5	WT6X13	WT6X17.5

DO YOU WISH TO SELECT PINNED-END STIFFENERS WITH A DIFFERENT NOMINAL DEPTH?  
(ENTER Y OR N)

? N

DO YOU WISH TO SELECT DIFFERENT STIFFENER SPACINGS? (Y OR N)

? N

DO YOU WISH TO EXECUTE THE RIGID FRAME STIFFENER DESIGN PROGRAM? (Y OR N)

? Y

## RIGID FRAME STIFFENER DESIGN

ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS  
(REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED TO HAVE THE  
SAME NOMINAL DEPTH)  
? 6

	RIGID FRAME STIFFENERS			
	SIDE 1	SIDE 2	SIDE 3	SIDE 4
STIFFENER SPACING (INCHES)	60	60	60	60
STIFFENER SECTION	WT6X9.5	WT6X17.5	WT6X13	WT6X17.5

DO YOU WISH TO SELECT RIGID FRAME STIFFENERS WITH A DIFFERENT NOMINAL DEPTH?  
(ENTER Y OR N)  
? N

DO YOU WISH TO SELECT A DIFFERENT STIFFENER SPACING? (Y OR N)  
(REMINDER: STIFFENER SPACINGS ARE THE SAME FOR ALL FOUR SIDES)  
N

DO YOU WISH TO EXECUTE THE PINNED-END STIFFENER DESIGN PROGRAM?(Y OR N)  
? N

## DUCT SECTION CHECKS

THIS PROGRAM APPLIES TO DUCTS WITH RECTANGULAR CROSS SECTIONS ONLY. DUCT SECTION CHECKS FOR DUCTS WITH OTHER THAN RECTANGULAR CROSS SECTIONS MUST BE ACCOMPLISHED BY HAND.

ENTER POISSON'S RATIO FOR THE DUCT PLATE

? .3

ENTER THE DUCT WIDTH (INTERIOR HORIZONTAL DIMENSION) IN INCHES

? 144

ENTER THE DUCT HEIGHT (INTERIOR VERTICAL DIMENSION) IN INCHES

? 168

ENTER THE DUCT SECTION CLEAR SPAN IN FEET

? 47.5

ENTER THE PLATE THICKNESSES (NOT INCLUDING CORROSION ALLOWANCES) OF SIDES 1, 2, 3 AND 4, IN DECIMALS OF AN INCH. (SIDE 1 IS TOP PANEL, SIDES 2 AND 4 ARE SIDE PANELS, SIDE 3 IS BOTTOM PANEL)

? .25,.25,.25,.25

ENTER THE INTERIOR PANEL STIFFENER SPACINGS FOR SIDES 1 THROUGH 4 IN INCHES

? 60,60,60,60

ENTER THE END PANEL STIFFENER SPACINGS FOR SIDES 1 THROUGH 4 IN INCHES

? 30,30,30,30

ENTER THE NOMINAL STIFFENER WEIGHTS, IN PLF, FOR SIDES 1 THROUGH 4

? 13,17.5,13,17.5

ENTER THE UNIT WEIGHT OF THE CORNER ANGLES IN PCF

? 490

ENTER THE EQUAL LEG CORNER ANGLES SELECTED FOR CORNERS 1, 2, 3 AND 4

NOTE: CORNER 1 IS THE "UPPER LEFT" CORNER OF THE DUCT, AND CORNER NUMBERING PROCEEDS CLOCKWISE AROUND THE DUCT. EXAMPLES OF THE INPUT FORMAT INCLUDE L3X3X4, L3.5X3.5X5, L4X4X8 AND L5X5X12, WHERE THE FIRST TWO NUMBERS IN THE INPUT STRING ARE THE ANGLE LEG LENGTHS, AND THE LAST NUMBER IS THE ANGLE THICKNESS IN SIXTEENTHS OF AN INCH. UNLESS SPECIAL CONSIDERATIONS DICTATE OTHERWISE, ALL FOUR CORNER ANGLES SHOULD BE THE SAME SIZE. THE LIGHTEST RECOMMENDED CORNER ANGLE IS L3X3X4.

? L3X3X4,L3X3X4,L3X3X4,L3X3X4

ALL OF THE DUCT SECTION DESIGN CRITERIA ARE MET FOR THE DUCT SECTION CONFIGURATION SHOWN BELOW

DUCT WIDTH (INTERIOR DIMENSION):	144 INCHES
DUCT HEIGHT (INTERIOR DIMENSION):	168 INCHES
DUCT CLEAR SPAN:	47.5 FEET

	SIDE 1	SIDE 2	SIDE 3	SIDE 4
PLATE THICKNESS (INCHES)*	.25	.25	.25	.25
INTERIOR PANEL STIFFENER SPACING (INCHES)	60	60	60	60
END PANEL STIFFENER SPACING (INCHES)	30	30	30	30
NOMINAL STIFFENER WEIGHT (PLF)	13	17.5	13	17.5

\* NOT INCLUDING CORROSION ALLOWANCE

	CORNER 1	CORNER 2	CORNER 3	CORNER 4
CORNER ANGLE	L3X3X4	L3X3X4	L3X3X4	L3X3X4

DO YOU WISH TO REEXECUTE THIS PROGRAM (DUCT SECTION CHECKS)? (Y OR N)  
? N

DO YOU WISH TO EXECUTE THE BEARING STIFFENER DESIGN PROGRAM? (Y OR N)  
? Y

## BEARING STIFFENER DESIGN

WHAT SHAPE BEARING STIFFENERS DO YOU WISH TO USE? (W = W SHAPE,  
 WT = STRUCTURAL TEE, C = CHANNEL)  
 ? WT

ENTER A TRIAL NOMINAL DEPTH (IN INCHES) FOR THE STIFFENER SECTIONS  
 (REMINDER: STIFFENERS ON ALL FOUR SIDES OF THE DUCT ARE DESIGNED TO HAVE THE  
 SAME NOMINAL DEPTH)  
 ? 6

## RIGID FRAME BEARING STIFFENERS

	SIDE 1	SIDE 2	SIDE 3	SIDE 4
STIFFENER SECTION	WT6X7	WT6X15	WT6X13	WT6X15

DO YOU WISH TO SELECT RIGID FRAME BEARING STIFFENERS WITH A DIFFERENT  
 NOMINAL DEPTH? (Y OR N)  
 ? N

THIS CONCLUDES THE DUCTWORK STRUCTURAL DESIGN PROGRAM

END

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